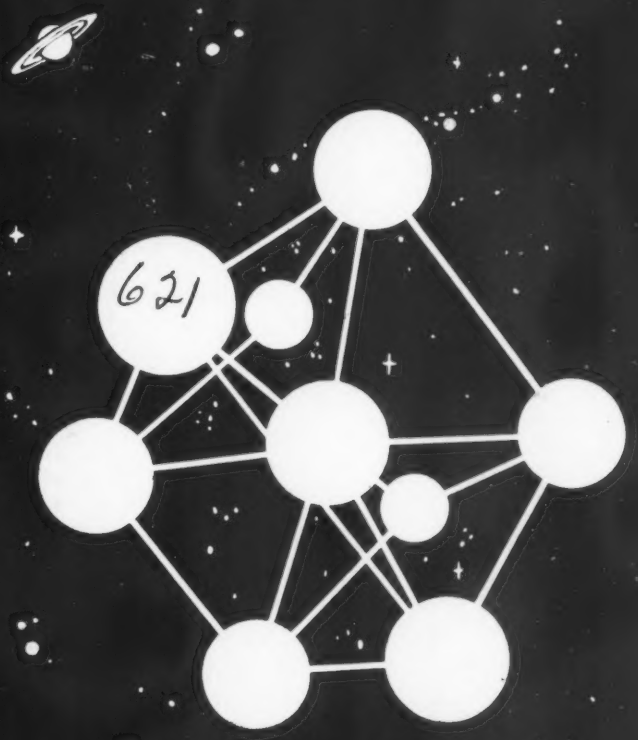
NUCLEAR ENERGY

THE JOURNAL OF THE INSTITUTION OF NUCLEAR ENGINEERS



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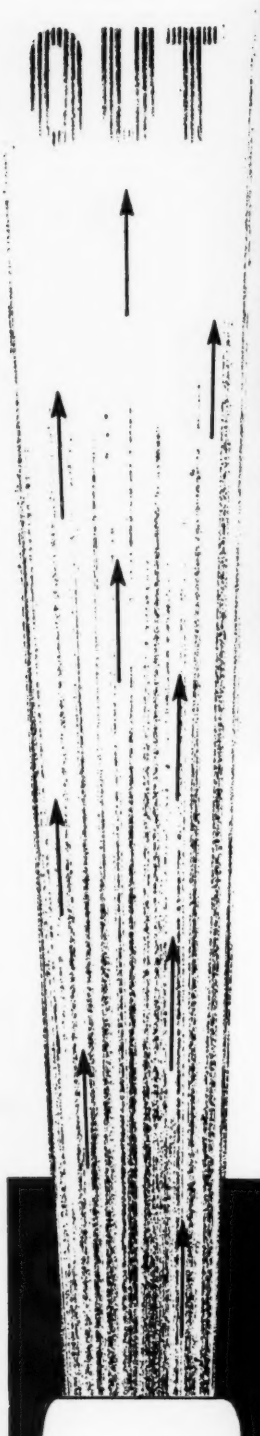

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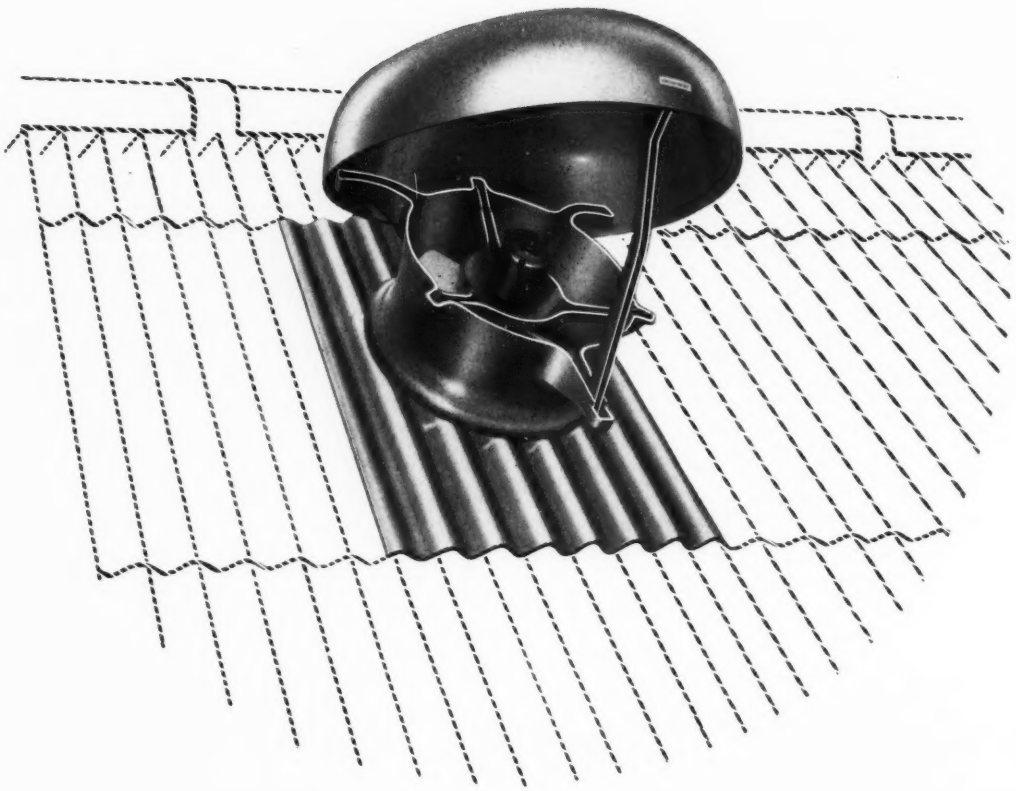

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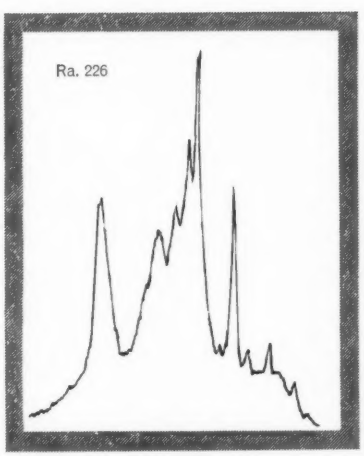

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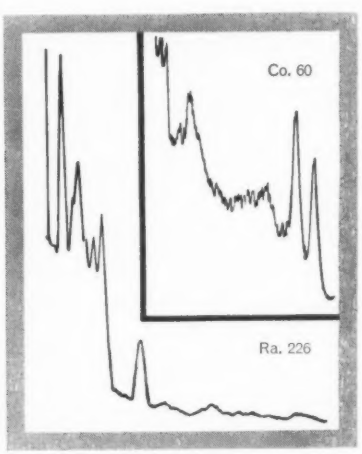

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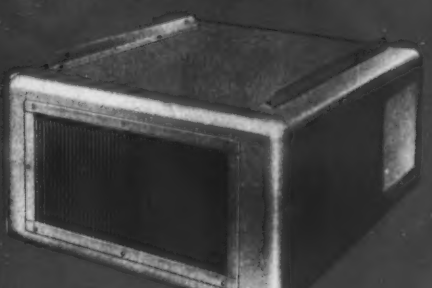

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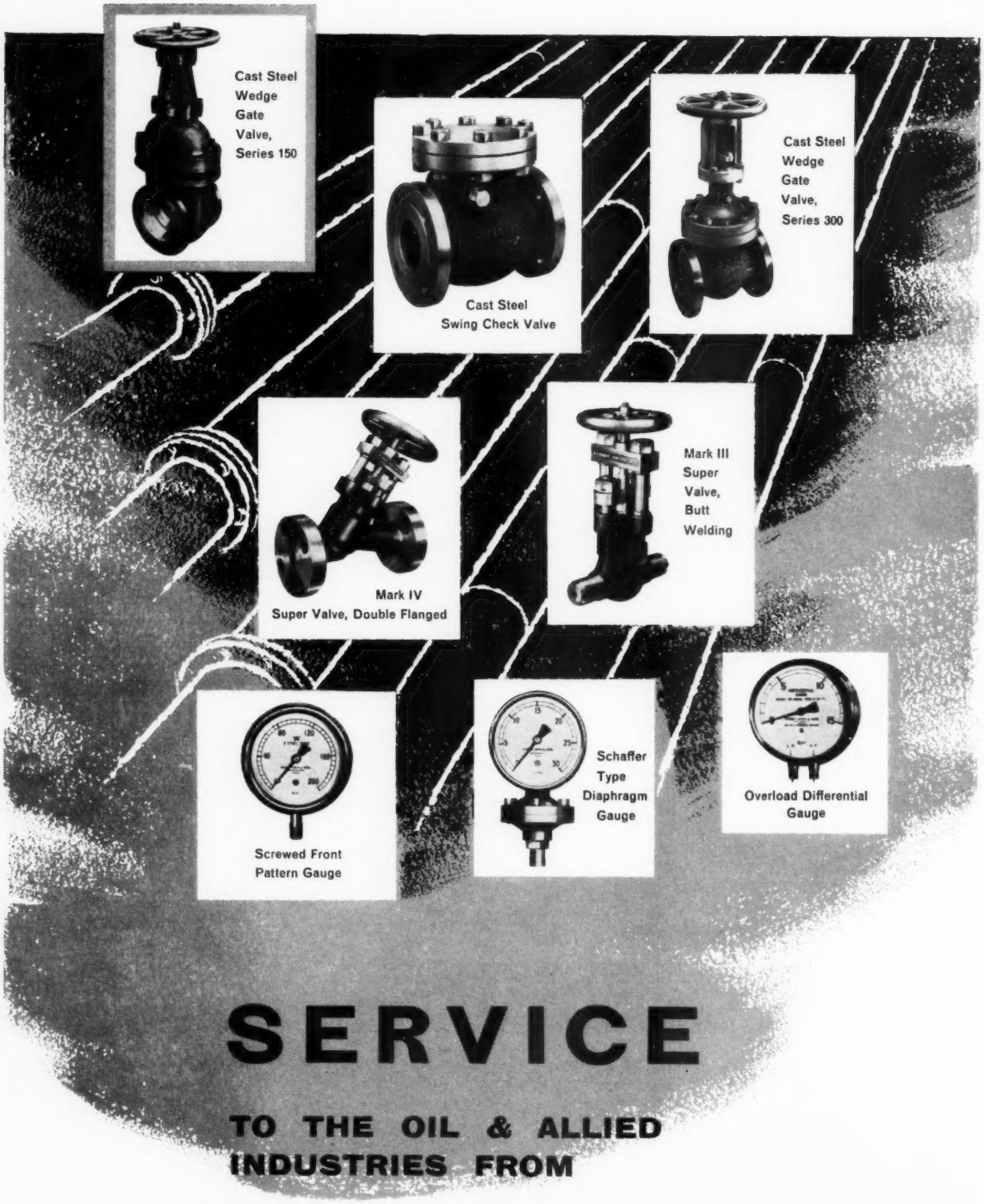
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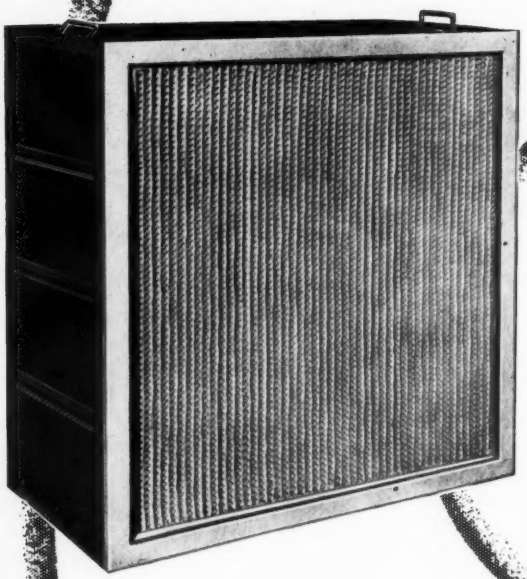

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Classroom and Laboratory

Arising out of a proposal by Dr. F. R. Paulsen, at a Council Meeting of the Institution of Nuclear Engineers, several hundred teachers of nuclear science were asked to report on simple apparatus and methods used or those which might be useful for practical demonstrations in instructional courses. The response was enthusiastic. From all parts of the world, from teachers in Universities, High Schools and Colleges, from research workers, manufacturers and public relations experts, have come many ideas. As a service to teachers, and also to other workers in nuclear fields, we are now publishing the many suggestions put forward. Each suggestion carries the identity of the person who put it forward, and also a reference number. The latter will facilitate enquiries sent in by readers requiring further information. Readers are invited to submit suggestions for inclusion in this feature

No. 87 Plant Radiographs

John H. Woodburn, Walter Johnson High School, Maryland, U.S.A.

The following is a very satisfactory method for preparing radioautographs of plants. Young vigorous weeds are the best plants to use. When the plants have been removed from the radioactive solution to which they have been exposed, they are rinsed, blotted and carefully placed on white card, rubber gloves being used. The plants are now covered with a plastic film and then with heavy cardboard. The film is tightly stretched, folded and then secured to the underside of the plant card. This transparent film protects the plants and prevents transfer of any radioactive material. In the darkroom the plants are now covered with X-ray film and then placed inside a light-tight envelope. The latter is weighted down with several books to ensure good contact.

The completed autoradiographs can be studied or exhibited in their natural state, printed in a photographic enlargement, contact printed, bound and projected as either 2 × 2 in. or " jumbo " lantern slides, or photographed against a white background. When appropriate, some of the material from which the autoradiograph has been prepared may also be mounted alongside the radiograph material.

No. 88 A Fall-out Experiment

This experiment not only emphasizes the nature of the fallout from nuclear weapons, but also assists in understanding the biological hazards and protective measures.

The " bomb " consists of an intimate mixture of 2g of powdered sulphur and 5g of powdered zinc, heaped on a sheet of asbestos board supported on a ring stand. Over this is sprinkled finely-powdered uranium ore or uranyl-nitrate (preferably immediately after ignition of the " bomb "). A small electric fan is placed on one side of the stand, to simulate a prevailing wind. Several newspapers are arranged around the stand. If a very large map of the district can be placed beneath this set-up, an even more realistic incident is possible. " Downwind " are placed, in various situations, a small tin of condensed milk (or similar canned material), a banana, an apple, and other suitable objects.

The " bomb " is ignited by means of a bunsen burner, onlookers being about 10 ft away. In order to improve results, a judicious sprinkling of radioactive powder over the area may be made. Monitor readings are taken after the smoke cloud has cleared, so that the " fall-out " is traced. Fall-out is highest nearest the explosion site, decreasing with increasing distance from ground zero. The demonstrator, wearing gloves, peels a banana carefully, and shows that the activity of the fruit is zero. A milk tin is washed well, and this again loses its activity, and the milk when the tin is opened proves to be safe to drink. The apple can be washed well and tested. The demonstrator should discuss the difficulties of decontaminating foodstuffs such as cereals, water, etc., and should stress the value of food protected by wrappers or other impervious coverings.

No. 89 Nuclear Radiation—A Work Unit in Physics

Robert D. MacCurdy, U.S.A.

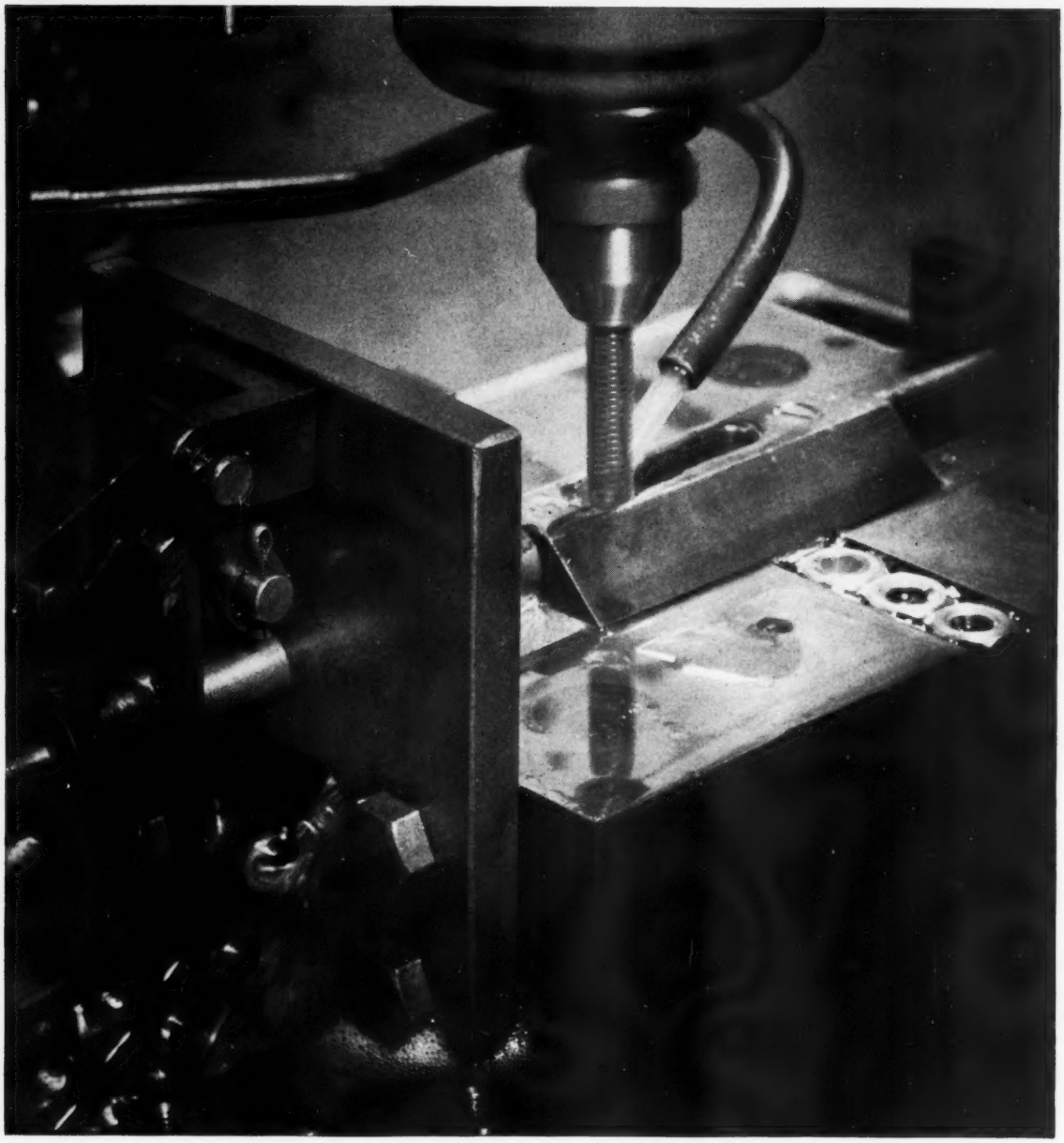
A philosophy of education in this atomic age is contained in a publication from the Science Section of the State Department of Education, Baton Rouge, Louisiana. This document, prepared by Simeon M. Weldon, is entitled " Nuclear Radiation—a Unit of Work in High School Physics."

The general purposes of a study of nuclear radiations are: (*a*) to provide a series of experiences to help a student to acquaint himself with his place and responsibilities in this technical world; (*b*) to help students improve their personal and civic worth to the college, the community, the state and the nation, through development of responsible and cooperative behaviour; (*c*) to extend an understanding of, and familiarity with, scientific devices, skills and procedures; (*d*) to orientate interests and aptitudes in relation to possible vocations; (*e*) to allow the student to express himself creatively.

In particular, there is the need to gain knowledge of radiations, atomic structure, radioactivity, nuclear careers, nuclear benefits, safety principles, and the location of nuclear devices and instruments. The student must be trained to think scientifically, to identify problems, gather data systematically, plan a solution, interpret, evaluate and generalize, and use instruments. The student, moreover, has to understand life in this nuclear age, the importance of nuclear developments and their role in medicine, etc., the dangers of radiations, and his responsibilities in spreading sound knowledge among other folk, the need for nuclear power and international control of nuclear energy, and the steps to be taken in the event of a nuclear attack.

The outline of the content of the educational scheme is as follows: atomic structure covers molecules, atoms, electrons, protons, neutrons, nuclei, size and mass relationships, isotopes. Early experiments are studied historically and include the work of Becquerel and the Curies, with the characteristic features of radium. Properties of alpha and beta particles and gamma rays are studied, with emphasis on nature, charge, ionizing power, penetration, occurrence and mode of entry into

Shell achievement



A famous aero-engine firm found it could drastically reduce the cost of producing nuts made from S.62 steel, by changing over from conventional cutting oils to Shell Garia Oil 115. The facts are these. S.62 steel is heat-resistant and stainless. The quality of this steel and the call for very fine tolerances, as well as a very high percentage of full depth of thread, presented costly manufacturing problems. The breakage of taps, the need for constant re-setting, and the high proportion of rejects, built up the average cost of the nuts to over 1s. 2d. each.

By accepting the advice of the Shell engineer and changing over to Shell Garia Oil 115, this firm was able to produce 3,000 nuts between regrinding taps–resulting in the cost of each nut being reduced to 3d.

Write for the booklet 'Selecting Your Cutting Oils' to Shell-Mex House, London, W.C.2.

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the body. Detection of radiations should cover instruments such as the Wilson cloud chamber, electroscope, Geiger counter and Civil Defence gamma meter CD U-720. Radiological defence aspects of fall-out include where to look for activity and the Federal network programme. Dose rate versus time is an important study. Artificially produced radioactivity introduces Van de Graaf generator, cyclotron, synchrocyclotron, synchrotron, cosmotron and bevatron. Under the heading "Uranium" appear the isotopes of uranium, the transuranic elements, fission, chain reaction and its control, nuclear reactors, atomic submarines and batteries, and isotopes applied to medicine and industry and the question of fusion and the H-bomb. The nature and sources of cosmic rays are also dealt with. The work unit is introduced via charts, drawings, pamphlets, books, detectors, devices and newspaper and magazine articles, use being made also of simple visual aids.

Student activities should be centred around the electroscope, its charging and discharging, diagrams of atoms, electrons, protons, the nucleus, charts of atomic structure, with readings and discussions on atomic structure. Industrial pamphlets and films can play an important role. Special features will include the following: (*a*) study discussions on radiations and their detection; (*b*) preparation of a glossary of atomic terms; (*c*) use of publications from the USAEC and firms; (*d*) construction and use of GM counter; (*e*) setting up a cloud chamber; (*f*) use of spinthariscope; (*g*) explanation and demonstration of CD GM counter; (*h*) effects of distance on gamma intensity; (*i*) effects of shielding; (*j*) effects of time spent near a source; (*k*) discussion on new developments; (*l*) visits to industrial and military sites; (*m*) drawing a Van de Graaf generator and explanation of its use; (*n*) writing of nuclear equations; (*o*) study of dose-rate *vs.* time; (*p*) other activities which may occur to the organizer. There should also be studies of new articles, the influence on architecture and manner of life, exploration of the universe and talks from prominent people on the political and world control of nuclear devices. Discussions on National Atomic Energy Act, 1946, and the U.N. Atomic Energy Commission, 1946, are also useful.

The document contains lists of materials for the course, lists of films and film-strips, and a bibliography of 13 books for students and seven for teachers. As culminating activities there is mention of the development of an informative programme for science clubs and groups, an exhibition project for school or science fairs, preparation of a class bulletin and dramatization of important discoveries. The whole publication presents a realistic course in instruction directed not so much to a complete scientific knowledge of radiations as to the role of adequate radiation knowledge in terms of citizenship.

No. 90 Handling Dry Isotopes conveniently

John H. Woodburn.

A convenient way to handle small quantities of radioisotopes in the dry form is to transfer a few drops of the one microcurie/ml solutions to circles or squares of dry filter paper, cement on to a tagboard card, label the card with the name of the isotope and the date of preparation and wrap the card with transparent film. A card made with two discs, one of P32 and one of I131, will show the relationship between the count rate and the distance of the source from the counter. Also, by combining two isotopes on one card, an interesting problem in decay rates is obtained. By exposing the discs to X-ray film when the isotopes are fresh and repeating this at 8-day intervals, the effect of decay rate is clearly seen. The count rate can be plotted against time and the resultant curves analysed from the four combined discs. Thus, the isotopes and their half-lives being known, one might be able to identify some unknown sources, if the decay curves for these are compared with carefully prepared cards. It must be remembered that the beta particles from P32 are more likely to reach the GM counter than those from I131, as the latter have lower energy. Again, the disintegration of the I131 atom produces a beta particle and a gamma ray, the latter travelling through a longer air column.

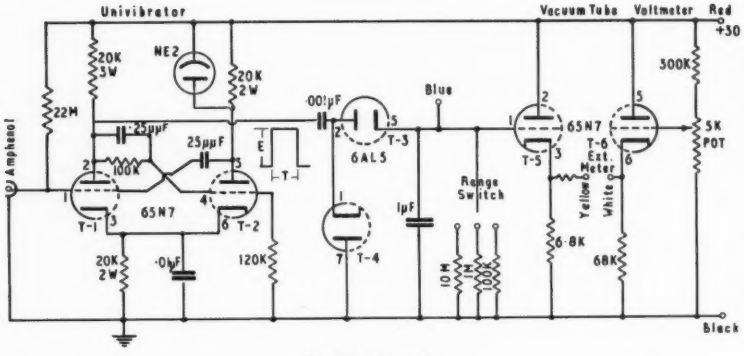
For a comparison of S35, I131, P32 and Zn65, paper discs are soaked in 1 microcurie/ml solutions of these, dried, cemented on to $2\frac{1}{4} \times 2\frac{1}{4}$ in. cardboard and wrapped in transparent film. The discs are then soaked with a pack of aluminium foil or lead foil sheets arranged so that the top edges of the discs are not covered. Nuclear rays from the discs encountered increasing numbers of sheets of foil further down the paper discs. The preparation is now covered with X-ray film and left in opaque paper for about 15 hr. The developed films show relative abilities of the radiations from the four isotopes to pass increasing thicknesses of whatever metal is used.

No. 91 A Count rate Meter

Dartmouth College, U.S.A.

This count rate meter was constructed by students of the physics course at Dartmouth College. Such a meter is a device for producing a meter deflection proportional to the rate at which voltage pulses are fed into its input. The usual method of doing this requires each pulse to add a fixed amount of charge to a capacitor, while letting the charge leak off the capacitor through a fixed resistor. Thus, the charge on the capacitor is proportional to the average rate of pulse arrival. The voltage across the capacitor is read off from a vacuum tube voltmeter.

Input pulses for the meter are obtained from the output of a conventional univibrator circuit utilizing the tubes *T-1* and *T-2*. This circuit produces a large uniform rectangular voltage pulse, whose duration is controlled by the choice of circuit constants, each time a small irregular pulse (*e.g.*, from a GM counter) is fed into the circuit. Normally, *T-1* conducts, the grid and cathode being at the same potential, enough grid current being drawn to keep the B+ voltage drop across the 2·2 megohm resistor in its grid circuit. Because of the voltage divider consisting of the 100*K* and 120*K* resistors in the grid circuit of the *T-2*, the grid of this triode is negatively biased beyond cut-off, so that it is not conducting. Because there is no current in the 20*K* plate resistor of *T-2*, the 25$\mu\mu$f capacitor connecting its plate to the grid of *T-1* is charged to the B+ voltage. When a negative pulse is fed into the grid of *T-1*, it is "turned off." At the same time *T-2* is "turned



Count rate meter

on," its grid becoming more positive when the current through the 20*K* plate resistor of *T-1* decreases. *T-2* continues to conduct until the 25$\mu\mu$f capacitor has discharged through the 2·2 megohm resistor and the grid of *T-1* returns to the cathode potential, at which time the circuit returns to its original state. Thus, the input pulse triggers the circuit, which goes over into a temporary state in which *T-2* is conducting instead of *T-1*. During this condition the plate voltage of *T-1* is greater than when it is not conducting. Thus, a positive output pulse can be taken off the plate of *T-1*. The Ne2 neon bulb across the plate resistor of *T-2* gives a flash each time a pulse is received.

Pulses from the plate of *T-1* are fed into *T-3* and *T-1* through a 0·001μf capacitor at the rate of *n* per unit time. The pulses are assumed to have a long enough duration for the capacitor to become fully charged with an amount *q* before the pulse ends. The charge flows on to the 0·001μf(c) capacitor from the 1μf(c) capacitor through either *T-1* or *T-2*, depending on the polarity of the input voltage pulse, which is positive in this case. C_2 is much larger than C_1 so that the voltage drop is all across C_1, and $q=C_1E$, where E is the height in volts of the pulse from the plate of *T-1*. The current into C_2 is $I=nq$. In the steady state, the same current I leaks off through the resistor (R) selected by the range section, so that the output voltage is $V=IR=nqR=NEC_1R$, proportional to *n*. The two tubes in the vacuum tube voltmeter are *T-5* and *T-6*. This circuit is essentially a balanced difference amplifier consisting of two cathode followers with the meter connected between the cathodes. The meter current, to a first approximation, is given by $(V\text{-}V_b)/R_M$, where in the circuit under consideration V is the voltage to be measured (at pin 1 of *T-5*), V_b is the potential at the grid of *T-6*, and R_M is the 510 series resistor in the meter circuit. V_b is adjusted until the meter reads zero when no pulses are being fed to the counting meter. This means that V and V_b are equal. If pulses are now fed to the counting rate meter, V rises (proportionally to *n*) and hence the meter deflection is proportional to V and hence to *n*.

No. 92 Use of a Simple Rate Meter by Beginners

Richard F. Blake, U.S.A.

In this simple experiment with a rate meter, the student makes a study of the effect of a screening material and constructs a plot of the effect of this material upon the rate of radiation. The student sets up a sample and meter in set position so that the reading is near the limit of the scale. There should be an inch or more between the source and the tube. The x10 and x100 scale will give better readings, those of the xL being usually too small. Records are kept of names, counter number, sample number, screening material, weight sq.cm, distance between source and GM tube.

Each group uses different screening material; examples are paper, aluminium foil, lead foil, or any uniform convenient material. A graph is plotted, using the number of sheets of screening material along the X axis, and the readings along the Y axis. It may be possible to recognize the percentage of counts due to beta and gamma rays by the change in the slope of the graph.

No. 93 Beginners' Experiment with Distance and Radiation

Richard F. Blake, U.S.A.

The purpose of this experiment is to study the effect of distance from a radioactive source upon the amount of radiation received. A radiation source is placed upon a table and its position marked so that it will not become displaced. The counter is placed on the table with the probe in the holder and the beta shield open so that the probe is parallel to the source and the meter reading is nearly at the maximum. The distance of the probe from the source is measured.

The meter is turned on and allowed to warm up for a minute before any readings are taken. The meter is moved a few inches away and the meter readings again taken. This process is continued until available space is used up, or until no appreciable count is registered. The counter is now moved gradually backwards again and the readings repeated. The results are reported under the following headings: distance, meter reading moving away from source, meter reading approaching source, average meter reading. These readings are plotted on graph paper, with distances on the X axis and the meter readings along the Y axis.

No. 94 Technical Information Sheets, UKAEA

Teachers of nuclear sciences will find both interesting and very informative a new series of Technical Information Sheets issued by the UKAEA. No. 1 in this series is entitled " The current output of heat energy from nuclear fuel and what it might be," a subject which is covered in 13 concise but informative paragraphs. As an example, para. 3 states that for a typical nuclear fission reaction such as $^{235}_{92}U+^{1}_{0}n=^{148}_{57}La+^{85}_{35}Br+3^{1}_{0}n$, there is the mass equation 235·124 + 1·009 → 147·961 + 84·938 + 3·027, which shows on the right-hand side a mass deficit of 0·207 mass unit, or $0{\cdot}207\times931=193$ MeV, or almost 200 MeV. This is equivalent to $3{\cdot}20\times10^{-11}$watt-sec, so that $3{\cdot}1\times10^{10}$ fissions/sec will produce 1w. A pound of U235 contains $\left(\frac{453{\cdot}6}{235{\cdot}124}\right)\times6{\cdot}023\times10^{23}$ or $11{\cdot}62\times$

10^{23} atoms, equivalent to 10·32m. kWh. Thus, 1 lb of U235, if completely fissioned at the rate of $3{\cdot}1 \times 10^{10}$ per sec, will give a power of 1w for $1{\cdot}032 \times 10^{10}$ hours. The energy released by the fission of all the atoms in 1 lb of U235 is $10{\cdot}32 \times 10^6 \times$ 3,413 B.t.u., equivalent to 3m. lb of coal of calorific value 12,000 B.t.u./lb.

Sheet No. 2 deals with some of the nuclear reactions taking part in fission reactors, while No. 3 is concerned with power theoretically obtainable from nuclear fusion. Sheet No. 4 is of particular value, since it covers the calculations of gamma doses from ionizing radiations and includes the definitions of the various units used. An interesting calculation shows that 1 curie of radiation from natural potassium would require no less than 1,220 tonnes of the material! No. 5 sheet deals with chain reactions and includes useful notes on cross-sections, threshold energies, neutron yields and types of reactions.

These information sheets are particularly useful, as they deal very concisely yet thoroughly with the mathematical aspects of nuclear power, an important aspect which is all too frequently side-tracked by teachers. This should be a very excellent series of publications.

No. 95 An X-ray Calculator

North American Philips Co., Inc., U.S.A.

We are all familiar with those paired-disc devices which offer so many types of information in a compact form, such as what seeds to plant and when, the time in various parts of the world, what stars can be seen from various localities at various times and so on. One of this species produced by the North American Philips Co., of U.S.A., should prove invaluable to all who work with X-rays for the identification of elements. Around the circumference of the larger disc are marked the values of the 2θ angles in degrees. On the smaller disc are given the types of crystal used in the instrument—mica (for transmission), lithium fluoride, rocksalt, calcite, fluorspar, quartz, gypsum, mica (for reflection). The line corresponding to the given crystal is set against the angular goniometer reading around the circumference. The wavelength and element-line can then be read off in the appropriate window in the smaller disc. There are three windows. On the inner edge of the innermost window is given the wavelength in ångstrom units, while on the outer edge of this same window the elements corresponding to the $K\beta$ lines are shown. The other two windows give similar information for the $K\alpha$, $L\beta_1$, $L\beta_2$ and $L\alpha$ lines. The price of this calculator is $1.00.

No. 96 Aids to X-ray Spectrography

Philips Electronic Instruments, U.S.A.

In 12 pages of well-chosen "Questions and Answers on X-ray Diffraction, Diffractometry and Spectrography," a booklet of this title provides in very concise form a veritable mine of information in this field. Broadly speaking, the three methods of X-ray analysis, namely diffraction, diffractometry and spectrography, are defined and evaluated and the conditions of operations, the uses, the advantages and refinements are adequately described.

Data Sheet RC-295 is a crystal and counter selection chart for use with the Philips Norelco X-ray spectrograph. The atomic scale of elements appears on the horizontal axis, while counters and crystals are shown on the vertical axis, these being applicable to the K and L lines. Crystals included are ammonium dihydrogen phosphate (ADP), ethylene diamine d-tartrate (EDDT), rocksalt, lithium fluoride, and topaz, while the counters are Geiger (argon or krpyton filled), scintillation, proportional and gas-flow. Most effective working ranges are indicated in all cases.

The fifth edition (1956) of an X-ray spectrograph chart for each element in the periodic classification up to californium shows characteristic secondary X-ray beams, angular positions and intensities being read on the instrument with a resolution of 0·5° or less. For the EDDT crystal, curves are given for the $K\alpha$ and $K\beta$ lines for elements Mg to Zn; for topaz crystal, the same lines are given for Ti to Re; for lithium fluoride crystal there are $K\alpha$ and $K\beta$ lines for A to Sn, and for rocksalt there are curves for the $K\alpha$ and $K\beta$ lines from S to Sn, the $L\alpha$ and $L\beta$ (first order) for Ag to Cf, and second order for Ba to Cf. This chart is a valuable summary of the characteristic X-ray lines and would be an excellent teaching aid when dealing with uses of X-rays and also when describing the work of Aston on X-ray spectra and atomic numbers.

No. 97 Measuring small amounts of wear

Robert F. Blake, U.S.A.

This has been a most successful experiment with elementary students and even very rough measurements give a reproducible graph. The method illustrates the industrial technique of measuring wear of materials such as engine pistons or car tyres, making use of radioactivity and the GM counter.

A solution of 3 microcuries of I131 is allowed to soak into one side of a wooden block, the solution being evenly distributed and allowed to soak in thoroughly. The weight of the block of wood is about 115 gm. The block is loaded with a 1 kg weight and it is then drawn across a sheet of smooth cardboard 8 in. × 10 in. and then across a similar-sized piece of sandpaper. Readings are taken with the radioactive face of the block touching the probe of the GM counter. The block is moved across the cardboard and sandpaper several times and the readings are recorded. The following figures are the results for an actual experiment:

Counts per minute	*Distance drawn over smooth cardboard, metres*
3,750	0
3,900	10
3,750	100
Counts per minute	*Distance drawn over sandpaper*
3,750	0
3,650	10
2,900	30
2,750	50
3,000	80
3,000	100
2,000	200
1,500	500
1,100	700
1,000	1,000
600	1,300
500	1,400

It is clear that little wear on the block occurs when it is drawn over the cardboard, but that there is progressive wear when the block is drawn over the sheet of sandpaper.

Analysis for Health

by F. R. Paulsen, BSc, PhD, FRIC, FCS, MINucE

WHEN the National Aeronautics and space Administration took over its new Plum Brook Nuclear Reactor Facility near Sandusky, Ohio, recently steps had to be taken to safeguard the health and safety of the personnel on the site and of civilians in the vicinity. A contract worth $270,850 was awarded to Controls for Radiation, Inc., of Cambridge, Massachusetts, for operational services covering radiation monitoring, surveillance and allied observations. The services performed include storage and dispensing of protective clothing and devices professional nurse services, monitoring of incoming and outgoing radioactive materials, disposal of wastes and collection of meteorological data. To carry out this responsibility, Con-Rad is establishing a permanent organization of over 30 people at the Plum Brook facility. The reactor facility will be centred around a tank-type reactor and the associated rocket facility will function as a satellite organization to the NASA Lewis Research Centre, some 50 miles distant.

Specialized experience

Controls for Radiation, Inc., is a company with very specialized experience in health physics, radiochemistry, radiobiology, electronics and physics. Their projects include at the moment a study of the biological effects of space radiations for U.S. Air Force, radiochemical analyses of samples of reactor cooling water from the U.S. Navy's nuclear submarines and aircraft carrier, the determination of strontium-90 in milk and other substances for the U.S. Air Force and the USAEC and an integrated health physics programme for the U.S. Air Force ARDC Command and Control Development Division.

A major part of the services undertaken by Con-Rad consists of biological assays, in which interesting techniques play an important role and which have made possible a careful watch on the health of personnel connected with radioactivity. Potential hazards to personnel, through inhalation or ingestion, are present in operations involving the processing or handling of radioactive materials such as uranium, thorium, plutonium and fission products. In order to assess the hazard continuously, a routine programme of examinations and assays becomes necessary. Bioassays are analyses of biological specimens such as urine, blood, sputum, etc., designed to determine the amount of hazardous material present. This information makes possible a correct evaluation of the efficiency of safety measures and equipment used in the potentially hazardous operations.

Recommended programme

A programme recommended by Con-Rad for a given establishment is likely to specify the type of analysis, frequency of sampling, personnel from whom samples are to be taken and so on. The customer has the responsibility of ensuring the co-operation of the personnel and in return gets reliable data quickly and economically.

An effective method for determining the amount of soluble toxic material inhaled or ingested by the body is the analysis of the urine. Although the major part of the soluble material taken into the body is usually quickly eliminated through the kidneys, some may become incorporated into organs and tissues of the body and will then pass out at a rate determined by the nature of the material and the biological half-life. The latter is not related to the radioactive half-life, but is the time taken for 50 per cent of the material to be eliminated from the body. This half-life may be a few months for loosely-bound materials, or many years in some of the awkward cases. Urine analysis will disclose whether exposure to the hazardous material is of the chronic or the acute type.

In acute inhalation or ingestion, the radioactivity level in the urine rises rapidly shortly after exposure, then decreases rapidly over a period of several days, then more slowly for some months or even years. This is the typical syndrome arising from soluble toxic material. In the case of insoluble material finding its way into the lungs, there is a much slower rise in activity and afterwards a slower decrease again.

Chronic exposure

With chronic exposure there will be a continuous radioactivity in the urine, rising at first slowly, then probably achieving an equilibrium level when the rate of elimination equals the rate of ingestion. With soluble substances the change of activity in the urine responds quickly to changes in exposure.

A 24 hr sample of urine, collected over a whole day, is most useful for general routine examinations, the results then being expressed as disintegration rate/day, *e.g.* 500 d.p.m./24 hr, rather than on a volume basis, *e.g.* 3 d.p.m./ml. However, for emergency cases, a spot sample taken from one voiding may be used for deciding whether or not there is any radioactivity present. A sample taken during the 24 hr immediately after cessation of work indicates exposure to both soluble and insoluble hazardous material, while the sample taken after several days indicates mainly the exposure to insoluble materials or incorporated substances.

A gross alpha analysis on a urine sample will indicate total exposure to hazards arising possibly from several alpha emitters. Extraction methods may be coupled by counting in a low background alpha counter, and if co-precipitation methods are employed, specific emitters may be determined. This is important since

alpha emitters vary enormously in their degree of hazard and should be determined separately.

Beta activity in the urine may indicate ingestion of fission products. It is important, however, to estimate the total potassium in the urine, since this element in the natural state has a slight radioactivity, because of the potassium-40 content. Correction for this must be made. The net count, *i.e.* gross beta count minus that due to K40 will be a measure of ingestion. The potassium may be determined either by means of the flame photometer, after ashing the sample, or as cobaltinitrite before ashing.

When the source of activity is known to be fission products, then a determination of gross fission products is used, these being precipitates by a basic phosphate method from an entire urine sample. The precipitate is filtered off, ignited, mounted and counted for beta activity.

Nuclides

It is sometimes necessary or advisable to examine the sample for specific nuclides, especially when the source of ingestion or inhalation is not known, or when there is more than one potential type of activity which could lead to mixtures of nuclides in the urine. Identification and measurement of individual nuclides permits evaluation of the radiation hazard with reference to the specific body burden of the isotope.

Uranium presents special problems. Soluble uranium is almost completly eliminated from the body in a few days, but insoluble forms remain much longer. A properly designed urine sampling programme combined with sensitive fluorometric analysis for uranium will provide important data for estimation of the amounts of soluble and insoluble uranium taken in. In the procedure used by Controls for Radiation, Inc. the sample is evaporated and dry-ashed, the ash being dissolved in a solution of aluminium nitrate. The uranium is extracted into ethyl acetate and an aliquot of this organic solution is transferred to a pellet of sodium fluoride-lithium fluoride mixture. This is fused and the uranium estimated by fluorometry.

Although enriched uranium will behave chemically in the body in the same way as the natural element, radiation damage in the body will be greater. Consequently, radiometric analysis of urine samples is necessary, the enriched uranium then being expressed as disintegration rate/time unit (*e.g.* 24 hr period). In the Con-Rad procedure, the uranium may be either extracted by organic solvents, or electroplated from the sample. In the former case, the whole sample, ashed, is extracted with ether, the uranium backwashed into water and then counted. In the second process an aliquot is ashed under oxidizing conditions and a solution carefully adjusted for *p*H is electrolyzed, the uranium being collected on metal discs for counting.

Plum Brook Nuclear Reactor Facility near Sandusky, Ohio

Specific analysis

Plutonium, collecting as it does in the bones, is a major hazard, as its rate of elimination is very small. Specific analysis must be used. Con-Rad evaporate a complete sample, ash, dissolve in nitric acid, reduce and then precipitate the plutonium on a lanthanum fluoride precipitate. This is dissolved, oxidized and the plutonium extracted into TTA, then again transferred to an aqueous layer in nitric acid, evaporated and counted.

Polonium is dangerous and may be inhaled or ingested during the preparation of neutron sources. The urine sample is electrolyzed at an adjusted *p*H value, the polonium being plated on a metal disc and counted.

Tritium exposure becomes increasingly possible, since its use is spreading, especially in tracer studies in medicine, biology and the like. It can be detected and measured very accurately using a liquid scintillation technique.

There may be occasions when special analyses have to be made for such elements as thorium, beryllium, mercury and so on.

While most generally urine samples are used in these examinations, there may be occasions when other biological materials may be better. This may be the case when there has been an accidental release of radioactive material into the air, or when entry into the body through breaks in the skin may occur. The types of analysis depend on which isotopes are involved, their physical and chemical forms, the time which has elapsed since the incident and the possible exposure time and so on. Nose wipes and sputum samples serve as very rapid indications of activity levels, but are not generally related in a precise way to radioactivity levels in the body. Blood samples may indicate how much radioactivity has entered the body, while faeces may yield information on insoluble materials which have not found their way into the urine.

Sample preparation

The preparation of samples for bioassays must be carefully done. Work clothes should be first removed, a shower taken and voiding should be made into special polythene bottles with disposable paper funnels. Each bottle must be carefully marked with a code number, which will be used on the report form after the analysis has been completed.

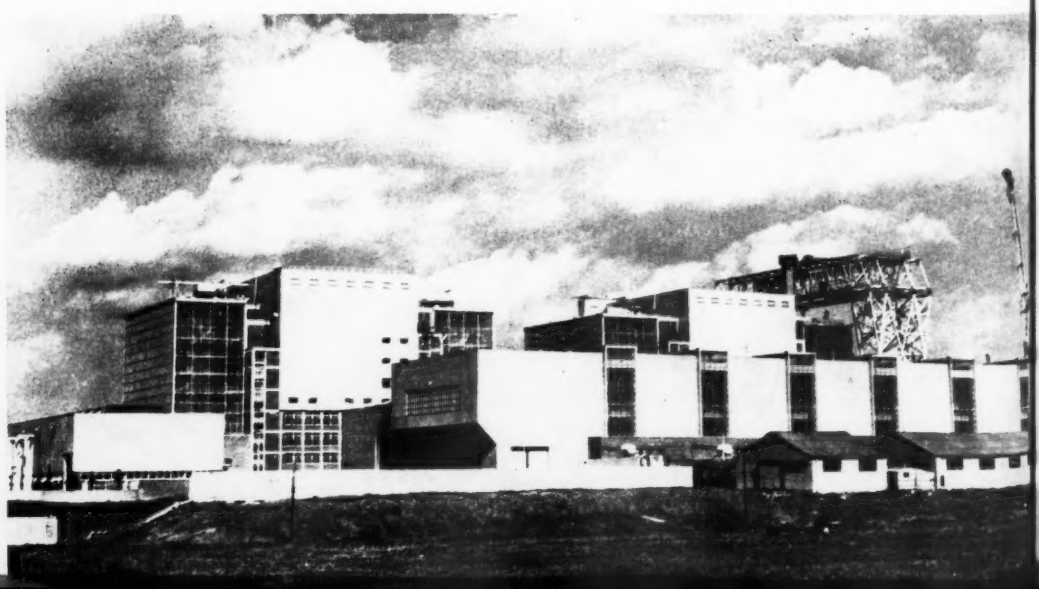
This description is typical of the close attention paid to details in services aimed at caring for the health and welfare of workers engaged in work where radioactivity hazards may arise. Such services must be accepted and approved as being just as essential as the recognized first-aid services which legislation makes necessary in most works and industrial undertakings. △△△

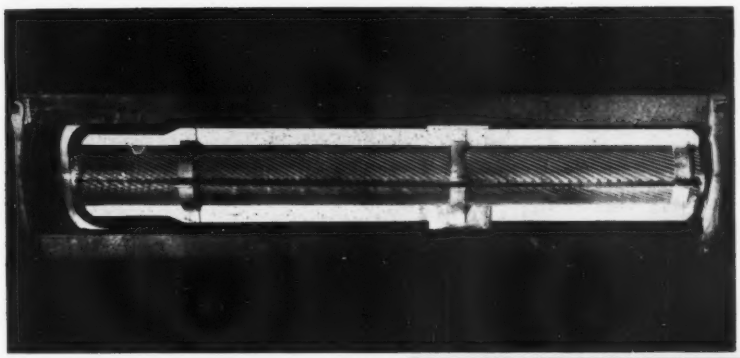
◀ Berkeley

FUEL goes into Britain's first two commercial nuclear power stations

BRITAIN'S nuclear power programme made a notable step recently when, for the very first time, uranium fuel was loaded into the reactors of Britain's first two commercial nuclear power stations. The stations are Bradwell (300 MW), on the Blackwater estuary in Essex, some 50 miles from London, and Berkeley (275 MW), on the Severn estuary, midway between Gloucester and Bristol. Berkeley and Bradwell have been designed and constructed for the Central Electricity Generating Board by The Nuclear Power Group and are the first two nuclear stations to be built in this country specifically for the generation of electricity.

Bradwell ▶

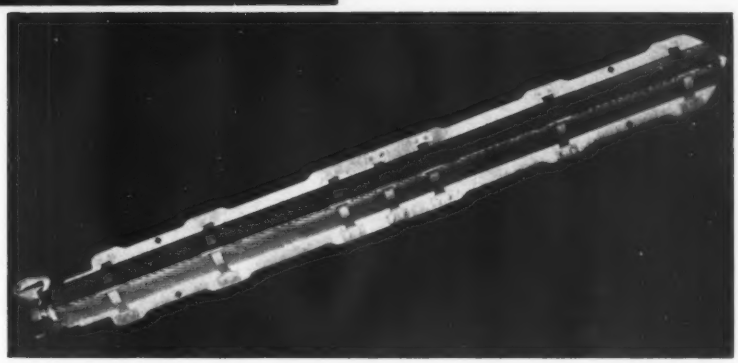




◀ **Berkeley**

The fuel elements for the two stations

Bradwell ▼



Permission to load fuel is given only after a licence has been issued to the Generating Board by the Ministry of Power's Chief Inspector of Nuclear Installations. When sufficient fuel has been loaded to achieve criticality, the reactor core becomes potentially radioactive and once the reactor has commenced operation above a certain power level, it is subsequently inaccessible except by remote control.

Although the first loading of fuel and subsequent achievement of criticality may be said to represent the true moment of birth of a nuclear reactor, some months of running trials both of the reactor and its connected generating plant must still elapse before the station as a whole can be connected to the National Grid and enter into full commercial service.

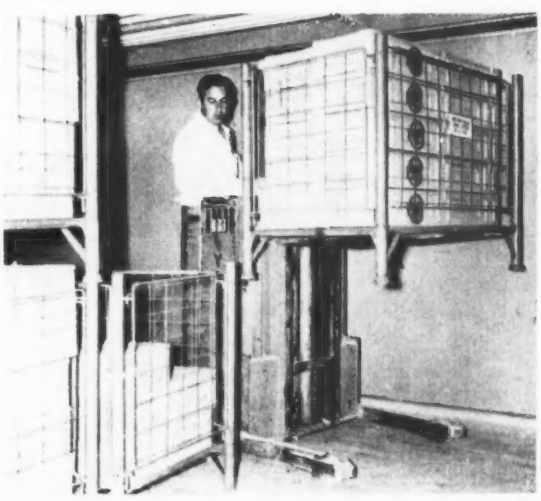
Full power operation from the No. 1 reactor at Berkeley is programmed for early 1962. The station will have two gas-cooled, graphite-moderated reactors, fuelled by natural uranium in metallic rod form enclosed in finned magnesium alloy cans. Berkeley has 3,275 channels per reactor with 13 vertically stacked fuel elements per channel, making 42,575 elements in each reactor. The total weight of uranium in each reactor amounts to 232 tons, with the 2,000 tons of the graphite moderator.

The coolant used to remove heat produced by uranium fission within the fuel elements is dry carbon dioxide gas circulated between the reactor and its eight associated boilers at a pressure of 125 lb/sq.in. Four turbo-alternators, each rated at 83 MW, generate electricity from the steam raised within the boilers.

Fuel rods

The natural uranium metal fuel rods used at Berkeley are each 19 in. long × 1·1 in. diameter. The finned magnesium alloy canister encloses each rod and each is mounted by

Berkeley — **Fuel is transported to the reactors in steel canisters. (*Left*) *En route* from the main fuel store at Berkeley and (*right*) the fuel element store in No. 1 reactor at Bradwell** — **Bradwell**



▲ *Berkeley*

After the polythene covers are removed the elements are inspected and placed in a special carrier

Bradwell ▶

two zirconium end brackets between two graphite struts, the whole assembly comprising one fuel element. Before fuel loading commenced in No. 1 reactor, a series of stringent pre-commissioning tests was carried out on the reactor and its associated plant in order to demonstrate their safety and correct operation. During normal operation of the reactor at full temperature and pressure, the nuclear fuel will be inserted into and discharged from the reactor core by a number of special machines mounted on the " charge face " floor immediately above the core.

The initial charge of fuel was, however, more conveniently and speedily loaded into the graphite core by hand. This was possible because at this stage, the reactor had not yet become radioactive.

It is interesting to follow the procedure of initial loading. All fuel arrives at site placed in metal containers and is received into the uranium fuel store (capacity 500 tonnes). As required, the sealed containers are transported by fork lift truck from the uranium fuel store to the reactor, about 100 yd distant. At the entrance to the reactor building, the container is placed in a lift and taken to a small store on the fourth floor of the building. Here, the container is unsealed and the fuel elements, each still separately bagged in polythene, are removed.

The elements are placed vertically in a small trolley and sent by a fuel lift to the fuel preparation room on the sixth floor. Here, where " clean conditions " are strictly observed, each fuel element is carefully inspected after removal of the protective polythene and loaded into a special carrier which, when fully loaded, is wheeled on a light trolley to the reactor charge face. The loaded carrier is then lowered by cable through a refuelling standpipe into the reactor pressure vessel.

Loading order

Inside the reactor vessel, operators stand on top of the graphite core structure, unload the fuel elements from the carrier, place them in a wheeled trolley and take them to the fuel channel to be loaded. The channel in the centre of the cylindrical core is loaded first. Adjacent channels are filled uniformly around it in an expanding circular pattern.

Before any fuel is loaded, 24 control rods in the central region of the core, out of a total of 132, are lowered and locked in the " down " position. These control rods cannot be withdrawn when manual fuel loading is taking place. The remaining 108 control rods are held in the " up " position, ready to drop in instantly in case of an emergency.

Neutron production

When 300 (out of 3,275) channels have been loaded, the operators leave the reactor vessel. It is then sealed and the 24 control rods are withdrawn. On the reactor charge face, physicists read from instruments the neutron production in the core.

This measurement having been taken, the 24 control rods are again lowered into the locked " down " position in the core, the vessel is unsealed and a further 100 channels manually charged.

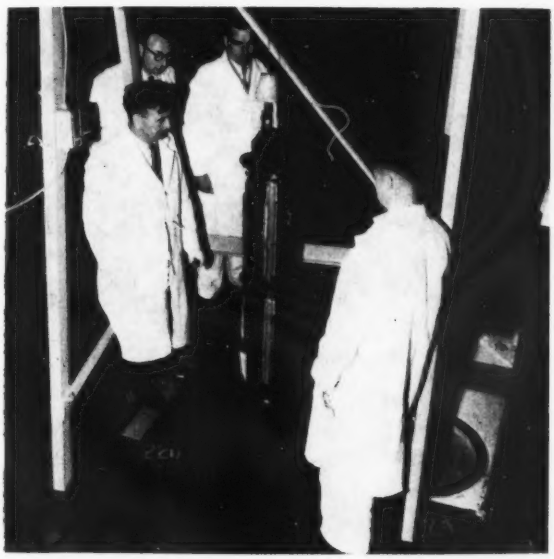
Once more, the operators leave the vessel, which is then sealed, the 24 control rods withdrawn and neutron production again recorded.

This operation is repeated with the number of fuel channels loaded between each test becoming progressively less. A curve is plotted of neutron production against the number of fuel channels loaded. From this curve, a forecast can be made of

the total number of channels remaining to be filled before the critical mass is attained. The loading procedure is continued until this point is reached. However, the reactor is still not allowed to "go critical," *i.e.*, produce a sustained chain reaction until a predetermined point in a series of tests carried out at that time to check the various nuclear design calculations.

Intensive tests carried out over a period of two weeks provide information concerning the nuclear data for the critical core. After completion of these tests, the loading of fuel continues by hand as before, punctuated by routine tests involving withdrawal of the control rods and establishment of sustained chain reactions at extremely low powers, until eventually the reactor is loaded with its full operational quantity of fuel. Up to this point, and in fact until the reactor has been run at quite substantial power levels, radioactivity is low enough to permit entry to the reactor vessel.

With the reactor fully loaded with fuel, tests are carried out to calibrate the control rods. Final tests in the series cover the equipment for the detection of faulty fuel element cans. The reactor is then ready for proving tests at increasing electrical loads, until full power is reached. The two reactors at Berkeley have a combined output of 275 MW.

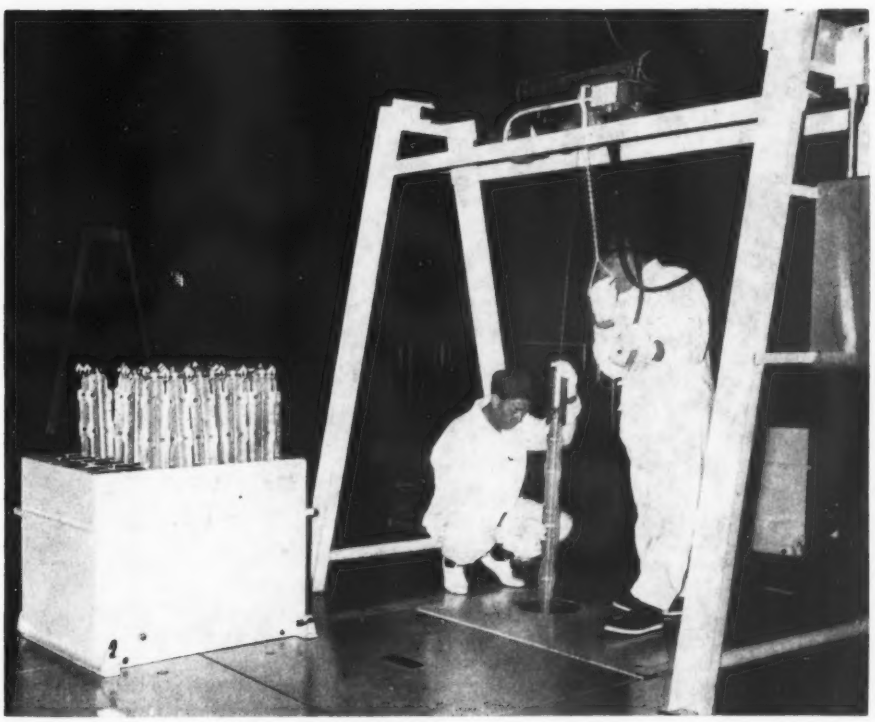


◀ **Berkeley**

Criticality

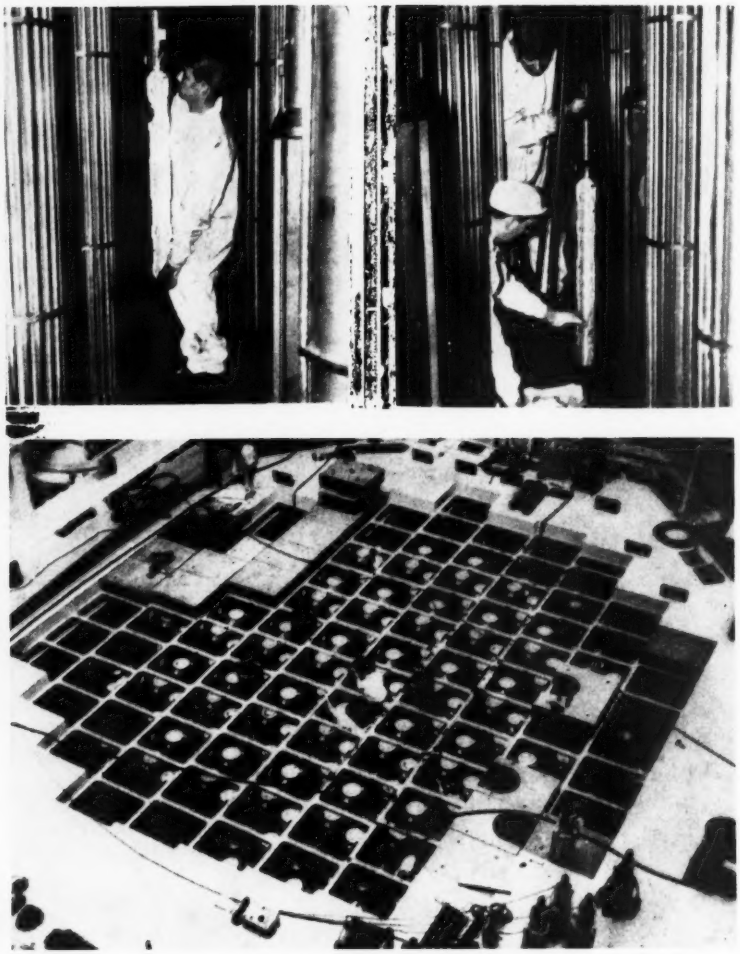
Filling of approximately 660 out of the total of 3,275 channels provides criticality. This represents a weight of fuel loaded of about 50 tonnes compared with the total of 232 tonnes required to bring the reactor to the fully operational condition.

Although only about 50 tonnes is required for criticality when all the control rods are withdrawn and once the reactor commences to operate, several influences tend to stop the reaction. For instance, increase in temperature of the reactor with power, and the production of fission



Elements are lowered through a fuel standpipe into the reactor

Bradwell ▶



◀ **Bradwell**

(*Extreme left*) **A fuel element is received on top of the graphite core; (*left*) lowering an element into a fuel channel in the core; (*Below left*) the No. 1 reactor pile cap at Bradwell**

by-products absorb neutrons and require compensation by inclusion of further quantities of fuel.

Factors such as these account for the additional uranium which has to be loaded into the reactor subsequent to the attainment of the critical mass.

Thus, the first loading of fuel and subsequent achievement of criticality may be said to represent the true moment of birth of a nuclear reactor. However, some months of running trials both of the reactor and its connected generating plant must still elapse before the station as a whole can be connected to the National Grid and enter into full commercial service.

Bradwell, which is also expected to be fully operational by 1962, also has two gas-cooled, graphite-moderated reactors, using natural uranium in a similar form to that described for Berkeley. Each Bradwell reactor has 2,564 channels, with eight vertically-stacked elements per channel, making 20,520 elements in all. The uranium in each reactor weighs 235 tons, the graphite moderator weighing 2,000 tons.

Here again, dry carbon dioxide gas is used as the coolant to remove uranium fission heat. The gas circulates at a pressure of 147 lb/sq.in. Six turbo-alternators, each rated at 52 MW, generate electricity from the steam raised within the boilers.

The Bradwell fuel rods are each 3 ft long × 1·15 in. diameter. The spiral fins of the magnesium alloy canisters are intersected by four longitudinal splitters.

The loading of fuel into the No. 1 reactor core at Bradwell also followed a period of intensive pre-commissioning tests.

Here again, during normal operation of the reactor, fuel elements will be loaded into and discharged from the core by a charge machine, but to speed up the loading of the first charge, the operation, involving the insertion of over 20,000 fuel elements, was accomplished manually using equipment specially designed for the purpose.

Fuel elements are delivered to Bradwell in boxes which are stored in rooms within the reactor building. As required, the elements, in their protective polythene sheaths, are removed from their boxes and placed in transfer baskets.

Baskets of elements from the reactor fuel storerooms are transferred to the pile cap, immediately above the shielded reactor pressure vessel, where an inspection area is located. The protective polythene covers are then removed and the fuel elements are taken, again in multi-position baskets, to loading positions on the pile cap.

Before any fuel is loaded, the total number of 120 control rods (which control the nuclear reaction by parasitic absorption of the neutrons) are fully inserted into the graphite core.

Loading teams

On the pile cap there are three open standpipes which communicate with the top of the reactor core within the reactor pressure vessel. It is through these that fuel is lowered into the reactor. There are two teams of operators—one on the pile cap, the other on top of the reactor core. The fuel elements are lowered singly through the standpipes by means of a special hoist to the operators on top of the reactor core. This team, aided by special hand grabs and friction pulleys, lower the elements in their positions within the channels in the reactor core.

Fuel loading commences at the central fuel channel in the reactor core and is continued outwards, maintaining a cylindrical pattern. The early stages of fuel loading are

interrupted at intervals and, with the reactor cleared of personnel, the control rods are withdrawn. A measurement of neutron flux on each occasion leads finally to a prediction of the critical loading.

Supercritical

The final stage of loading to criticality is designed to make the reactor slightly supercritical so that the reactor power will continue to rise when the control rods are withdrawn. This power divergence will be arrested at a very low power level by automatic reactor trip, thus demonstrating the achievement of criticality and the adequacy of the automatic safety devices.

To achieve criticality at Bradwell it is only necessary to fill approximately 474 (out of 2,564) channels. The weight of uranium fuel in these channels amounts to 38 tonnes.

After a particular stage in the fuel loading programme has been achieved, the reactor is in a condition where withdrawal of the main control rods will cause the reactor to "start-up." In order to protect against this condition whilst operators are working inside the reactor, precautions are taken which consist of:—

(i) Control of control rod operation by which the control rods are locked in the disengaged position and the person guarding the reactor access is "custodian of the keys."

(ii) Provision of neutron flux instrumentation which would detect a rise in flux level occasioned during a start-up and would de-energize all control rod systems. This would ensure all control rods dropping into the core by gravity and hence shutting down the reactor.

With one reactor fully loaded with fuel elements, the period of reactor measurements will continue when attention will be paid to the installed systems of control rods, absorber elements, burst cartridge detection equipment, channel coolant flow adjustment facilities, etc., all of which must be checked, assessed and adjusted where necessary to provide optimum operating conditions when the reactor is finally brought to full power operation. △△△

Letter to the Editor

Radiation polymerization of Methyl Methacrylate

A member writes: I was greatly intrigued by the article in your May issue by Prof. Joklik on the radiation polymerization of methyl methacrylate. I fear that the article might give a false impression to your readers on the possibility of radiation polymerization of methyl methacrylate. A long time ago the UKAEA carried out work with the ICI, The Distillers Co. and with a number of other large polymer companies in this country on this very subject, and there is little doubt that radiation initiation of polymerization is unattractive economically when compared with free radical initiation. There are, however, very much more interesting possibilities in industrial uses of radiation at the moment. For example, at low temperatures ionic polymerization can be induced. Radiation can be used to modify catalyst properties, cross linking of rubbers is possible giving materials which have improved high temperature properties and last but not least, the radiation sterilization of heat sensitive medical products as, for example, plastic hypodermic syringes is already an established process. A pilot plant for this purpose containing a source of 200,000 curies is already in operation at Wantage. While radiation polymerization of methyl methacrylate is unattractive since the product obtained using radiation has the same physical properties as is obtainable using conventional initiation there are a large number of other exciting possibilities. △△△

Monographs received

The Application of Low Voltage Radiography to Magnox AL80, by G. F. Linsley. Published by The Reactor Group, UKAEA, Risley, Warrington. Reference TRG Report 6 (S). Available from H.M. Stationery Office. Price 3*s* 6*d*.

A Method for Routine Determinations of Tritium in Urine Using a Coincidence Liquid Scintillation Counter, by J. Sandalls. Published by Medical Division, AERE, Harwell, Berkshire. Reference AERE R3716.

Some Radiation Syndromes and Treatment, by Katherine Williams. Published by Medical Division, AERE, Harwell, Berkshire. Reference AERE R3728. Available from H.M. Stationery Office. Price 5*s*. 6*d*.

Some tests on Lithium Glass Scintillators for Detecting Neutrons, by D. H. C. Harris. Published by Nuclear Physics Division, AERE, Harwell, Berkshire. Reference AERE M827. Available from H.M. Stationery Office. Price 3*s*.

Analytical Method for the Absorptiometric Determination of Combined Nitrogen in Zirconium Metal and Zircaloy, presented by Chemical Services, Operations Branch, Springfields. Published by Production Group, UKAEA, Risley, Warrington, Lancs. Reference PG Report 15 (S). Price 1*s*. 9*d*.

Analytical Method for the Determination of Particulate Uranium on Atmospheric Dust Adhesion Plates, presented by Chief Chemist, Laboratories Division, Technical Department, Capenhurst. Published by Production Group, UKAEA, Risley, Warrington. Reference PG Report 224 (CA). Price 1*s* 9*d*.

Analytical Method for the Determination of Plutonium in the Feed and Product Solutions of the Windscale Primary Separation Plant (Complexometric Titration), presented by Technical Manager, (Chemistry), Technical Branch, Windscale Works. Published by Production Group, UKAEA, Risley, Warrington. Reference PG Report 210 (W). Price 2*s*. 6*d*.

Analytical Method for the Determination of Yttrium-90 and Lanthanide Fission Products in Reactor Fuel Processing and Effluent Treatment Plant Solutions, presented by Technical Manager, (Chemistry), Technical Branch, Windscale Works. Published by Production Group, UKAEA, Risley, Warrington. Reference PG Report 206 (W). Price 1*s*. 6*d*.

The Determination of Impurities in Beryllium by Activation Analysis Using Remote Reactor Facilities, by A. P. Seyfang and R. Todd. Published by Production Group, UKAEA, Risley, Warrington. Reference PG Report 172 (S). Price 3*s*.

Radiostrontium and Radiocaesium in Drinking Water in the United Kingdom, Results to December, 1960, by R. N. Crooks, R. G. D. Osmond, T. J. Webber. Published by Health Physics and Chemistry Divisions, AERE, Harwell. Reference AERE-R3552. Available from H.M. Stationery Office. Price 3*s*. △△△

Stress-relieving at Hunterston

STRESS-RELIEVING of the first 70 ft diameter reactor pressure vessel at Hunterston nuclear power station has now been successfully completed. In this operation about 1,800 tons of steel situated at an average height of 85 ft above ground level was heated to a temperature of 550°C., soaked for 12 hours and then allowed to cool slowly. A high degree of control was essential to prevent the temperature difference bet een any two points in the vessel exceeding a specified maximum.

The operation was carried out simultaneously on the inner heat shield, the core-support grid and the main gas seal between the walls of the inner heat shield and the pressure vessel. Certain portions of the hot and cold gas ducting and the nozzles for the charge/discharge and control-rod standpipes which penetrate the pressure shell were also included. The steel restraint beams for the graphite core were suspended from the inner shell nozzles and other items treated at the same time were laid on top of the grid cover plate.

The station is being built for the South of Scotland Electricity Board by the GEC and Simon-Carves Atomic Energy Group. Construction of the pressure vessels was sub-contracted to the Motherwell Bridge and Engineering Co. The heating system for the stress-relieving operation was proposed and designed by the Industrial Advisory Service of the South of Scotland Electricity Board.

Radiant heating

Because of the difficulty of achieving uniform heating by natural convection alone it was felt that radiant heating should be adopted. The heaters had to be arranged in zones with external means of varying the heat output of the heater groups in each zone. In order to obtain the best possible heat transfer from the heaters to the fabricated structure, it was better that the heaters should not be surrounded by insulation or sheaths. It was decided to employ heaters in the form of alloy strips.

To achieve good electrical insulation characteristics the heater strips had to be widely spaced from earth and from each other. Considerable expansion of the whole heating system would take place at the high temperatures involved so good clearance between live sections was a prerequisite.

The material used for the heater strip needed to have a high resistivity, so that a robust arrangement could be employed, and be sufficiently ductile for ease of forming. A low temperature coefficient of resistance and good resistance to progressive oxidation when hot were also necessary.

Separate insulators were necessary because bare conductors had to be used to obtain maximum radiation. These needed to have a high resistivity at high temperatures; to be resistant to mechanical and thermal shock; and to have a high mechanical strength in tension and compression under working conditions.

The pressure vessel and included components were heated by a series of freely radiating Brightray strips supported by wire links and ceramic insulators. Some strips were mounted circumferentially between the spherical pressure vessel and the cylindrical inner heat shield while others on the top and bottom crowns followed approximately the curvature of the vessel.

With the system of heater suspension employed, a curtain-like structure of heater elements was built up in the space between the inner heat shield and the pressure vessel.

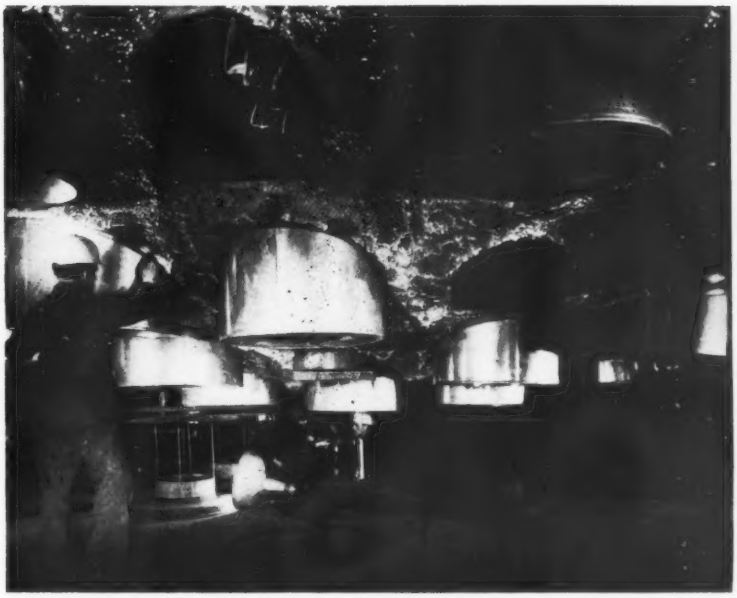
Brightray heater strips were also placed beneath the grid to ensure

Electric heating strips being installed under the grid of the first reactor at Hunterston before the stress-relieving operation. The slotted angle framework was used to support the heaters for the bottom crown of the 70 ft diameter pressure vessel

adequate heating there. Enclosed tubular-type heaters were employed for each of the gas ducts.

A very flexible suspension method was adopted which allowed one heater to be switched off without fear of damaging the suspension of neighbouring heaters.

The fabricated structure was divided into 40 separate heating zones (including gas ducts). By choosing suitably dimensioned heating strip, 100 ft (30·5 m) lengths connected directly across the 240v mains could be used. This length of strip was chosen because it was half the circumference of the spherical pressure vessel and enabled the supply to be brought in at one side of the vessel and the neutral connection to be taken out of the other side.



Application of Rocksil thermal insulation to the bottom crown of the reactor pressure vessel. Each charge nozzle was insulated individually and then covered by a thin aluminium container

Brightray strip

Except for the ducts, all heaters were made of Brightray strip. For the top crown the section of each heater strip was slightly reduced. Inside each zone the heater strips were connected in groups, each group being supplied from an externally-mounted auto-transformer fitted with voltage ratio adjustment. This allowed a measure of control to be exercised over individual heating groups.

Each duct heater was of stainless steel construction, 8 in. in diameter and 6 ft long, with a rating of 24 kW at 240v. Two heating units were used in each hot gas duct, and one heating unit in each of the shorter cold gas ducts.

Although the linkage system between element arrays varied from zone to zone, only one type of ceramic insulator was used throughout the whole installation.

All the support links were of Incoloy DS wire which at 800°C. has a tensile strength of 10·5 ton/sq.in. The stress in the most heavily loaded link at this elevated temperature was less than 0·1 ton/sq.in., so that a high mechanical factor of safety was provided. This wire has a melting point of not less than 1,320°C. and a coefficient of expansion of $18{\cdot}5 \times 10^{-6}$/°C.

Temperatures were measured at some 400 points by means of chromel-alumel thermocouples. All the internal and external positions for the permanent thermocouples were used and in addition a number of temporary points were selected. The readings from these thermocouples were recorded by two different instrumentation systems described later.

Particular attention was paid to the positioning of thermocouples on the pressure-vessel support skirt, gas-duct stubs and sphere. It was possible to record the temperature distribution down the support skirt in various planes around its periphery. This enabled a check to be made on the performance of the thermal pocket at the top of the skirt.

The temperature along each gas-duct stub was measured at several points to ensure that no large temperature gradients occurred. In addition, four pairs of thermocouples were connected differentially to record any temperature variation between selected points at the top and bottom of the large irregular-sectioned forgings at the duct roots.

Two thermocouples, one connected to the top crown and the other to the bottom crown, were arranged to indicate the temperature difference between the two points, thus enabling the controller to regulate the heat input to maintain an even temperature distribution throughout the pressure vessel.

The vessel divides symmetrically into four quadrants and it can be assumed that the heating pattern is similar in each quadrant. It was decided, therefore, to connect strip-chart recorders to the thermocouples in one quadrant only, with a few check thermocouples in the other quadrants.

In addition to the thermocouples used for the pressure vessel and its contents, about 20 were placed in the surface of the concrete biological shield at the equator level, on the concrete beams forming the soffit and in the concrete supporting the reactor skirt, to ensure that the rise in concrete temperature was not excessive.

Thermocouples were also used to measure the temperature of the heater strips at various points.

Two special instrumentation and recording systems were employed to eliminate human error. About 300 of the thermocouples were connected to a digital typewriter recording system which reproduced the temperatures as a printed list, while the rest were connected to six strip-chart recorders. There were two reasons for this, firstly the strip-chart recorders could be used to control the heating cycle for a limited period should the digital typewriter system fail, and secondly the strip-chart instruments provided a record which could be interpreted more quickly and easily than that of the digital typewriter.

As temperature readings were taken from the recorders they were plotted on a specially-constructed peg board in the control room. Temperature was plotted horizontally (in 5°C. steps) and the 100 thermocouples were plotted vertically. Thus by plotting the readings of these thermocouples during the stress-relieving operation an overall picture of the heating pattern was presented.

Two models

Adjacent to this board were two models, one of the pressure vessel and the other of the inner heat shield resting on the grid. Small lamps were fixed to these models in positions corresponding to those of the 100 thermocouples represented on the peg board. By placing a small plug in a thermocouple position on the board the appropriate lamp on the model lit up. This arrangement allowed the position of a thermocouple in the vessel to be located quickly if it showed that the temperature in that part was differing too widely from the mean temperature of the whole structure. The difference could then be corrected by reference to electrical control information on the peg board.

Forming part of the peg board were two other display systems. The first showed the power loading of each heater circuit in the pressure vessel and the tapping position of each of the 24 auto-transformers; and the second the cycling of the tubular duct heaters.

When on automatic operation all the thermocouple readings were sequentially scanned and printed out by an electric typewriter. If required, special observation of particular thermocouples could be achieved by selecting and printing fewer temperatures more frequently. On manual operation, by the use of a push-button, individual thermocouple readings could be selected and logged by the control engineer.

Four uniselectors with gold-plated contacts, each handled one quarter of the 300 thermocouple circuits. The uniselectors were driven by relays which were electrically interlocked with the indicators and print-out system to control the logging sequence.

The output side of each uniselector was connected to an Electroflo type 198 potentiometric indicator scaled to read 1,000°C. The balancing time of the indicator was nominally one second, but if the difference between the two successive temperatures was small, this time was greatly reduced. In order to take advantage of this, balancing detectors were fitted so that print-out was initiated immediately all four indicators were balanced.

Once during a complete scan (*i.e.*, through all four uniselectors), each indicator was connected to a standard reference, corresponding to a reading of 800°C. This provided a means of checking whether the logging installation was functioning correctly.

Accuracy of the potentiometric indicators was 0·25 per cent. f.s.d., and the accuracy of translation was ±1 digit. The system was calibrated at 550°C. and a correction card made to cover other temperatures.

Since the electric typewriter was able to print 10 digits/sec, multi-bank uniselectors capable of switching the inputs of the four indicators simultaneously were employed, the four outputs being printed-out sequentially. The print rate for this was 2½ digits/sec.

Additionally the five differential thermocouple readings were registered on a separate chart recorder so that special and continuous observation of them was possible.

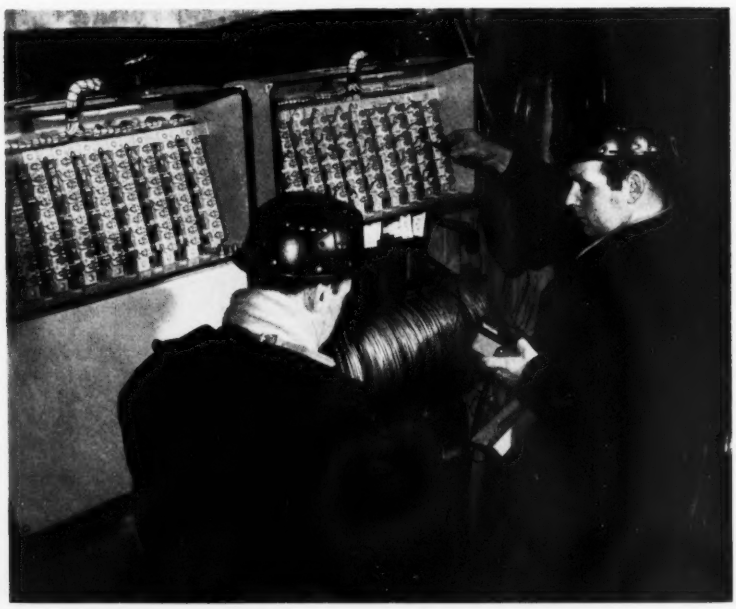
Power supplies

Because of the high temperature involved, special arrangements were adopted to take the power supplies to the heating elements and from the thermocouple points inside the pressure vessel. Stainless-steel conductor rods were used for the power connection to the heaters, groups of these rods being taken in through the charge nozzles to supply the bottom crown and grid heaters, through cold gas ducts to supply the curtain and through the control-rod nozzles to supply the top-crown heaters.

Welded connections were used between all the heater strips and the stainless-steel rods since it was imperative that no faults should arise at these points when stress-relieving was in progress.

Mineral insulated stainless-steel-clad cables were used for all thermocouple leads. These cables were grouped together and brought out through nozzles in the pressure vessel. At suitable points outside the pressure vessel the m.i. cables were terminated in junction boxes from which normal multicore cables were run to eight further junction boxes in the control room. The leads from these boxes were then taken to the temperature-scanning equipment. Maximum power demand never exceeded 2 MW/ton of metal treated.

All external surfaces of the pressure vessel, ducts and nozzles were



Checking the connections for some of the 400 thermocouples used

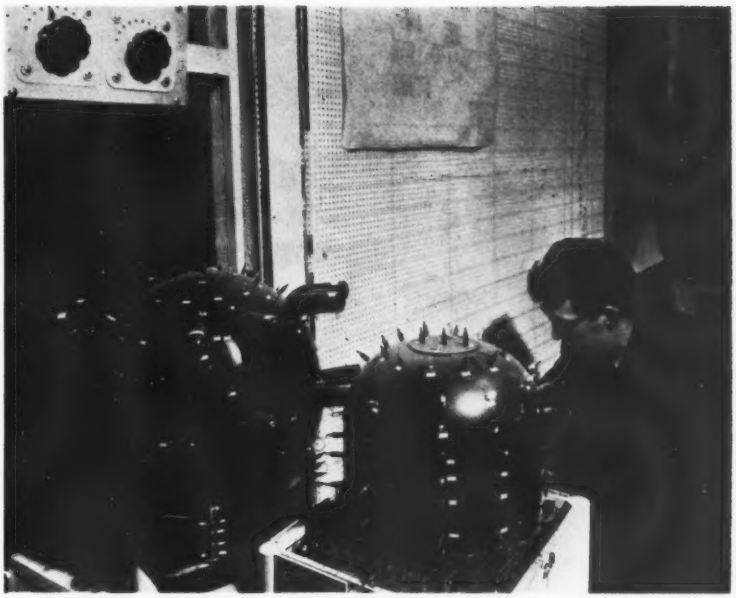
insulated to reduce heat losses. In most cases this insulation consisted of two 3 in. thick layers of Rocksil but in some instances, namely round the duct stubs and skirt, the thickness was increased to 12 in. Aluminium foil was widely used to reduce radiation and so protect the concrete surfaces.

The inner layer of Rocksil had a density of 9 lb/cu.ft and was backed on each side with a layer of 1 in. mesh galvanized wire netting. The outer layer was of similar construction but its density was 6-7 lb/cu.ft and a 0·001 in. layer of aluminium foil was interposed between the insulation and the wire mesh on the outer face.

Experimental work had already established that a 12 in. thickness of Rocksil was required on each side of the vessel support skirt to achieve an acceptable temperature gradient down the skirt under reactor operating conditions. Further investigation indicated that this was satisfactory for the stress-relieving operation also. The increase of thickness of insulation on the duct stubs where they passed through the 8 ft square openings in the inner biological concrete shield ensured that the temperature of this concrete did not exceed 150°F. As a further precaution against undesirable increases in the temperature of the concrete, arrangements were made to pass about 300,000 lb of air/hr through the biological shield cooling system.

New experience

Lack of previous experience in controlling the heating rate of vessels of this size and complexity meant that it was not possible to lay down a set of rules governing the operation. For this reason the bottom crown heaters were switched on initially at their lowest setting, *i.e.*, half load, and held at this level until the heating pattern emerged. Switching instructions were then based on this pattern. It was agreed to limit the rate of temperature rise to less than 5°C./hr and on this basis it took about seven days for the pressure vessel to reach the stress-relieving temperature of 550°C. at which it was soaked for 12 hours. Throughout the whole operation there was not a single heater failure. As would be expected the overall rate of heating was controlled by that of the bottom crown, because natural convection tended to take the heat away from this part of the sphere. After the soaking period the vessel was left to cool for nine days before removing the thermal insulation. Entry to the vessel was delayed a further two days.



These two models were used to establish the position of 100 selected thermocouples set up for the stress-relieving operation. In the background can be seen the peg board used to provide a graphic picture of temperatures throughout the pressure vessel

Subsequent to stress-relieving, a number of tests have been carried out on the fabricated structure. These tests were laid down by Lloyd's Register of Shipping (Land Division), with the approval of the UKAEA, the South of Scotland Electricity Board and the consultants to the Board, Kennedy & Donkin. They included crack-detection tests on 10 per cent. of all nozzle welds on the inner heat shield and the grid, and 100 per cent. crack-detection tests of the nozzle welds in the shell and on the gussets. Ultrasonic examination of selected areas on the top and bottom crowns was also carried out.

The absence of any faults in the pressure vessel or its contents indicated that the stress-relieving was entirely successful. Certain minor modifications to the layout of the heating system should result in a reduction in the time taken to treat the second reactor pressure vessel. The use of radiant-heating strips, freely suspended inside the vessel, has been fully justified by the result.

One advantage of the system used is the ease with which it can be dismantled and to a large extent used again for the second reactor. △△△

Trade Literature

" Pumping " is the title of a new 12-page illustrated brochure now available from Parkinson Cowan Measurement, Tameside Works, Oldham. This, the second in a new series of three, outlines the construction of the firm's range of Rotoplunge pumps. This versatile pump, which has only three parts, has applications throughout industry. Details of its features and of specimen applications are also included. There is also a section describing the Shoflo sight flow indicator, an effective device which shows at a glance whether liquid is flowing through a pipeline.

In a new brochure which we have received from Associated Lead—" Lead for Radiation Protection "—up-to-date information is supplied about lead in the atomic field. Technical details are given on the mechanical properties of lead, the forms of lead shielding bricks available and some of the alternative methods of providing reactor shielding. A section is also devoted to a new material called " Densithene," a composite lead/polythene product of particular importance in dealing with neutron and gamma-ray shielding. A special section deals with the use of lead in X-ray work.

Nuclear Training and Research Equipment

by Otto F. Joklik

(Although the author originally intended this article to conclude with Part IV in our September issue, he has now agreed to continue the article for several more issues).

THREE sub-critical experiments are at present being designed and constructed for the United Kingdom Atomic Energy Authority in collaboration with the Reactor and Engineering Divisions at Harwell and illustrate the type of design and manufacture which Vickers is ideally suited to undertake. In each case the equipment has been specially designed for a new research problem.

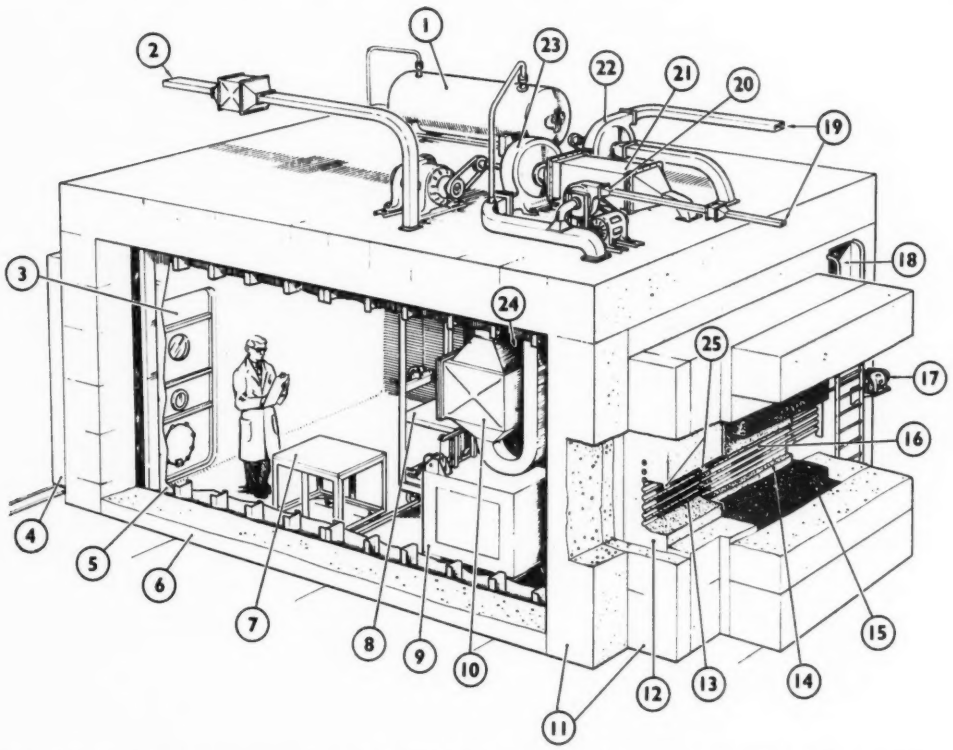
Exponential Experiment

This apparatus has been designed for graphite moderated exponential experiments conducted with advanced fuels. Neutron counts will be plotted at temperatures between ambient and 400°C.

The graphite stack is variable in frontal area from 5 ft square to 12 ft square; the depth along the fuel rods being 7 ft or 9 ft 4 in.

Radiant electrical heating is employed on the side faces only, leaving the front and rear faces free for rod movements and coolant flow. Pile cooling is achieved by a closed circuit air or inert gas system which enters the working face and leaves at the rear face of the pile. The pile stands in an insulated primary chamber and all operations at elevated temperatures are conducted through a sealed door mechanism.

The pile chamber occupies one end of the containment vessel, the other end forming the personnel chamber. The sealed door between the two compartments has two operating features. The main door is hinged in the

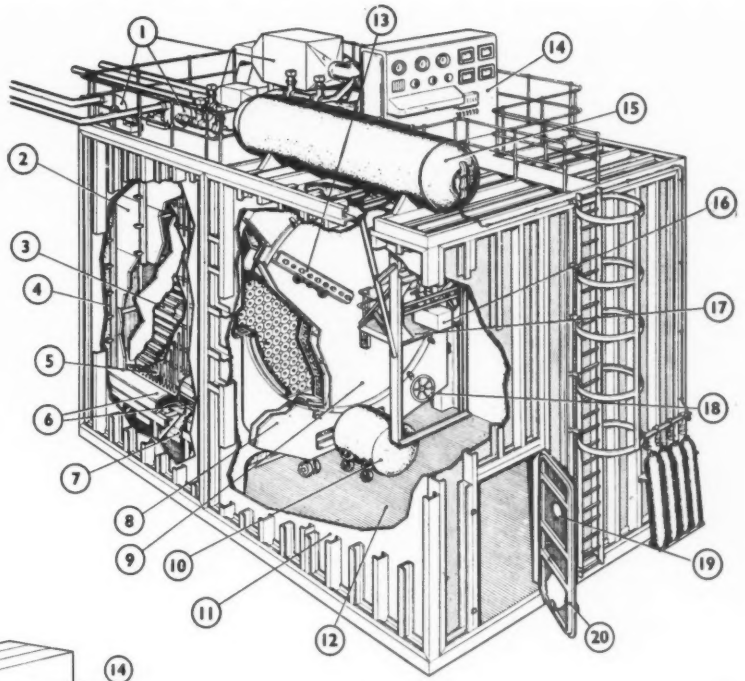


Heated and contained fine structure assembly. Key:—1 Inert gas supply; 2 Personnel ventilation inlet; 3 Personnel access door; 4 Sliding concrete door; 5 Secondary alpha containment; 6 Biological shield reinforced concrete; 7 Working table; 8 Transfer box; 9 Preheating oven; 10 Graphite block cooler; 11 Removable concrete blocks; 12 Slug store; 13 Antimony slugs; 14 Source plinth; 15 Graphite reflector; 16 Beryllium tubes; 17 Slug operating mechanism; 18 Emergency exit; 19 To stack; 20 Differential pressure blower; 21 Heat exchanger; 22 Personnel chamber blower; 23 Pipe cooling blower; 24 Pile chamber primary alpha containment; 25 Lead plugs

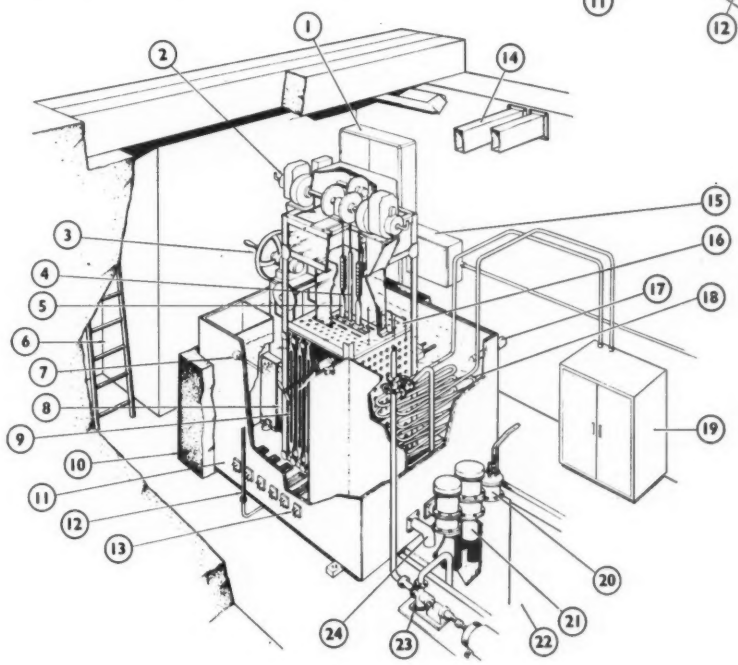
normal manner which provides access for erection of new lattice configurations. The swinging door mounts a second circular door provided with an access slide; rotation of the door and movement of the slide allows the operator to insert a flux detection rod into any of the measuring holes in the pile.

Pressure differentials are maintained so that leakage can only occur away from the experimental area into the pile chamber.

The uniform thermal neutron fluxes are supplied by four radium-beryllium sources distributed in a graphite plinth under the pile. A suitable source flask is used for transport and storage of all the sources simultaneously. Fixed and mobile thermocouples are provided for installation in the graphite assembly and preheat oven, for equipment inserted into the pile. The heating



(*Above*)
Heated and contained exponential experiment. **Key:**—1 Pile cooling and personnel ventilation system; 2 Sindanyo insulation; 3 Main pile; 4 Micafil insulation; 5 Heating mats; 6 Insulating floor; 7 Plinth; 8 Main pile door; 9 Circular door; 10 Coffin; 11 Alpha containment; 12 Personnel chamber; 13 Slide mechanism; 14 Control console; 15 Inert gas cylinder; 16 Oven; 17 Pile access platform; 18 Circular door control wheel; 19 Window; 20 Personnel door



(*Left*)
EUREKA approach to critical facility. **Key:**—1 Contractor cabinet; 2 Winching gear; 3 Shutter lifting gear; 4 Control rod; 5 Shut off rods; 6 Ladder access; 7 Neutron source control rod; 8 Shutter; 9 Reactor core; 10 Biological shield; 11 Reactor main tank; 12 Water level gauge; 13 Immersion heaters; 14 Cable trunking; 15 Busbar chamber; 16 Detectors; 17 Level switch; 18 Refrigeration coils; 19 Refrigeration unit; 20 Manually operated dump valve; 21 Solenoid operated dump valves; 22 Dump tank; 23 "Mono" pump motor and accessories; 24 Weir outlet

cycle, which takes a maximum time of 48 hours, is controlled automatically and recorded. Top temperature trips avoid overheating.

Continuous-running alpha monitors are incorporated and all ducts to atmosphere are guarded with glass paper alpha filters. Fire precaution equipment is installed to handle outbreaks in either chamber. All controls and instrumentation are grouped on a single console mounted on top of the containment. The control operator communicates with the personnel chamber by means of a two-way loudspeaker inter-communication system.

Fine Structure Experiment

The fine structure experiment provides primarily for the study of intracell neutron distributions in lattices containing various fuels. Experiments will be conducted both cold and with the fuel and moderator uniformly heated to any temperature up to 400°C.

The graphite for the heated assembly consists of machined blocks forming a rectangular stack of maximum dimensions 6 ft × 6 ft × 4 ft 8 in., the latter dimension being the length in the direction of the fuel channels.

The stack is heated by radiation from electric fire bars situated on the top and bottom faces. It is cooled by a closed-circuit air or inert gas system entering and leaving the pile chamber on the same faces as the heaters. The stack is enclosed in a primary containment and access to a central block of graphite is obtained through a sealed door.

A large-area antimony-beryllium source is provided to give the necessary uniform flux of thermal neutrons. The beryllium tubes are housed in a fixed plinth on one face of the stack, radioactive antimony being inserted when radiation is required. Owing to the intense gamma radiation produced, the antimony is held in a source flask while operators are working on the pile and is inserted mechanically from an external control console.

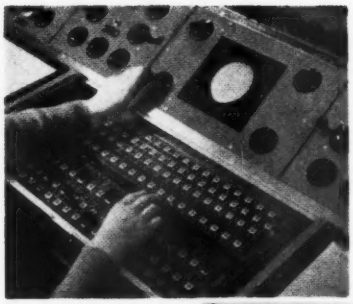
The pile chamber is installed inside a second containment, known as the personnel chamber, which also houses a preheat oven and a cooling box. Flux measurements are made by measuring the activity of foils embedded in a central block of graphite inserted in the pile and it is necessary to cool this block within a half-hour of completion of an experimental period. The cooling box operates with the same cooling circuit as the pile chamber; the full flow being diverted for this purpose.

The personnel and pile chambers are kept below ambient pressure, the pile chamber pressure being the lower of the two. Any leaks that may occur must therefore be inwards and away from the operators. The outside of the personnel chamber is shielded with concrete blocks to absorb the radiation produced while the pile is active.

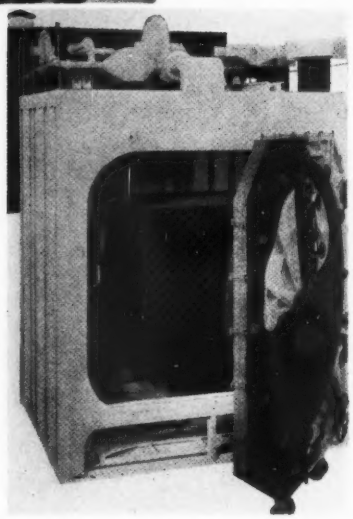
Because of gamma activity, several safety circuits are incorporated to ensure that the source cannot become active while personnel are within the shield area.

To cater for the activation of the antimony slugs, provision is made for loading and unloading a transport flask from the source flask adjacent to the pile. The chambers and their associated blowers and heat exchangers communicate with the atmosphere via glass paper alpha filters, limiting the efflux particle size to less than one micron. The outlet gases are vented to atmosphere through a chimney stack which, together with the inlets, is situated outside the experimental building.

Analogue computers providing research simulator data



Programming the design department's analogue computer. This maths service is supplemented by a digital computer provided with tape punching facilities



Section of model of the heated and contained exponential experiment showing close-up of pile chamber door

Sub-critical Assemblies

A sub-critical experiment, entitled EUREKA, for a water-moderated reactor is in course of construction. This type of equipment is suitable for an approach to criticality experiment.

EUREKA has been designed to permit investigation of the effects of varying fuel rod assemblies which are placed in a tank of demineralized water, having a temperature range of from 0°C. to 80°C., the volume of which can be varied as required.

The pile operates at zero energy; is remotely controlled and the associated electronic equipment incorporates all necessary safety interlock devices. The grid structure has been designed to permit the arrangement of fuel rods in varying numbers and patterns. A neutron source in a lead shielded container is housed in the tank. A removable lead-filled shutter permits the source to be fed towards the fuel rod assembly and BF_3 proportional counters are fitted to measure the neutron flux.

Heating and refrigeration equipment are installed in the main tank and an agitator ensures efficient mixing. Specially designed dump valves are fitted to enable the main tank to be emptied rapidly in cases of emergency: two of the three valves are solenoid operated and are linked to the controlling equipment. A dump tank is provided and fitted with a pump unit to return the water to the reactor tank.

A motor-driven cadmium rod is raised or lowered between the fuel elements for fine control of activity. Two larger section cadmium rods are poised over the pile for insertion whenever a critical figure is registered by the control equipment.

Reactor Simulators

Reactor simulators may be divided into two distinct types, namely for training and for research. They are based on analogue computer principles and continuously solve the kinetic equations relating neutron population with time in a nuclear reactor.

Vickers can provide simulators to meet any positive requirement.

Training Simulators

Training equipment, suitable for university, technical college and atomic training establishment installation, has been developed for the simulation of nuclear reactor performance under variable operating conditions. The simulator is fitted with a reactor control console for use in training operators or to study the effectiveness of automatic control systems. It may also be set up to represent a particular power station reactor for training shift pile operators.

Besides being much cheaper and occupying less space than a reactor, greater liberties can be taken in performing power changes. All essential safety devices are incorporated; a wide range of thermal or fast fission reactors running at low power may be simulated and the fuel content changed as required, from say U235 to U233, Pu239, or a fictitious two-group type fuel. Selector switches are provided for setting up various conditions related to, for example, control and movement or neutron source, so that all the variables needed to assess the behaviour of nuclear reactors under operating conditions may be simulated.

Research Simulators

Research simulators can cover a wide range of reactor designs and can be provided in a form similar to the general purpose computers installed at Vickers as depicted.

They are capable of wider application than training simulators which, except for power station applications, do not normally provide for the investigation of thermal and poison effects, or for the study of automatic control devices. △△△

Institution News

THE Second Institution Annual Dinner will be held at the Savoy Hotel on Thursday, November 2nd at 7 p.m. for 7.30 p.m. Guest of Honour is to be Dr. Rush of America. Music will be provided by the Royal Artillery Orchestra. Cost exclusive of wines will be £2 5s. 0d. per head. Tickets are now available from the Institution offices.

More Papers

Arrangements have now been made for two more Institution papers; the first will be given by Dr. Paulsen on " Nuclear Teaching," at Caxton Hall on November 10th, 1961, at 6 p.m. for 6.30 p.m. The second will be given by Captain Atkins of Vickers on " Nuclear Propulsion," also at Caxton Hall after the AGM on December 8th, 1961. It is also hoped to hold a meeting in January when Dr. Hecht of Germany will give a lecture.

New Council Chamber in use

The first Institution Council Meeting in the Institution's new Council Chamber took place on September 8th. Council Members present, left to right, are Dr. Paulsen, D. S. Watt, Sir John Duncanson, H. E. Cooper, H. F. Jones, Dr. W. J. Jenkins, and P. Spear. Dr. N. S. Grassam and J. B. Pinkerton are sitting on the left behind Dr. Paulsen

New Members—Elected 20th June, 1961

Fouad Abdulla Hussain, Iraq.	AM	S. Holcroft, Sutton Coldfield.	M	R. J. Morgan, London.	JM	R. C. Thurston, Sutton Coldfield.	AM
J. A. Allcott, Birmingham.	AM	G. Howes, Gateshead, 10.	AM	K. R. Norton, Wolverhampton.	AM	C. Turner, Somerset.	AM
K. W. Bowden, Somerset.	M	Y. Irving, Castle Bromwich.	M	R. Parr, Knutsford, Cheshire.	AM	K. J. Watson, Birmingham.	AM
D. Broadley, Lancashire.	AM	J. K. Jefferies, Solihull.	AM	A. Smith, Slough.	AM	T. F. Waters, Cumberland.	AM
Capt. D. G. Gross, B.F P.O. 10.	AM	H. B. E. Johnson, Castle Bromwich.	AM	G. Stevens, Leicester.	AM	J. R. Wilcox, Sutton Coldfield.	M
H. J. E. Hayes, Birmingham.	AM	J. L. Lloyd, Brighton.	M	J. H. Taylor, Belper, Derby.	AM	R. W. Wimblett, Abingdon.	AM

C. F. Leyse

Captain Pattison

(*Above*) **H. A. C. McKay**

(*Below*) **P. T. Fletcher**

PEOPLE

The composition has been released of the board of directors of Nuclear Developments, Ltd., the private company formed recently by Imperial Chemical Industries, Ltd. (Metals Division), Rolls-Royce, Ltd. and The Rio Tinto Co., Ltd. **MR. J. N. V. DUNCAN,** OBE (managing director, The Rio Tinto Co., Ltd.) is to be chairman of the new company and the board will consist of the following members: **R. W. WRIGHT** (deputy managing director, The Rio Tinto Co., Ltd.); **SIR MARK TURNER** (director, The Rio Tinto Co., Ltd.), **J. D. PEARSON** (chief executive and deputy chairman, Rolls-Royce, Ltd.), **A. A. RUBBRA,** CBE (director, Rolls-Royce, Ltd.), **L. BARMAN** (special executive, Rolls-Royce, Ltd.), **DR. J. TAYLOR,** MBE (director, Imperial Chemical Industries, Ltd.), **ST. J. de H. ELSTUB,** CBE (chairman, ICI Metals Division), **DR. R. L. P. BERRY** (director, ICI Metals Division). The executive director and general manager of the company will be **MR. S. S. SMITH** (research manager, ICI Metals Division) who has been closely associated with nuclear engineering since 1941. Mr. Smith has made important contributions to the development of diffusion membranes for isotope separation and has since been continuously concerned with research and development work on specialized nuclear engineering materials. **P. J. G. ELWES** (The Rio Tinto Co., Ltd.) will be secretary of the company and reactor expert.

CERN now has a new director general, **PROFESSOR V. F. WEISSKOPF,** who has recently replaced **DR. J. B. ADAMS.** Dr. Adams is to become director of the Controlled Thermonuclear Research Establishment at Culham. Professor Weisskopf has for the last year been a member of the CERN directorate responsible for research. Mainly interested in theoretical physics, Professor Weisskopf's major work is a 900 page book "Theoretical Nuclear Physics" written in conjunction with John M. Blatt in 1952.

The appointment was announced recently of **DR. MAURICE GOLDHABER** as director of Brookhaven National Laboratory. The previous director, Dr. Leland J. Haworth has been appointed a member of the United States Atomic Energy Commission. Born in 1911, Dr. Goldhaber worked for a period at the Cavendish Laboratory under the direction of **LORD RUTHERFORD.** At Brookhaven since 1950, Dr. Goldhaber has been concerned with the study of nuclear isomers and fundamental particles. Since 1960 he has been chairman of the physics department at Brookhaven.

New deputy general manager of Plessey Nucleonics, Ltd. is **CAPTAIN G. R. B. PATTISON,** CBE, BSc, MIEE, RN (Retd). Until recently Captain Pattison was assistant director of electrical engineering with the director general, ships, Admiralty, Bath.

CARL F. LEYSE has been appointed general manager of the Internuclear Company of Clayton, Missouri. Mr. Leyse has had considerable experience in the nuclear field and was concerned with the development of the Materials Testing Reactor at the Argonne National Laboratory.

The UKAEA has released **MR. P. T. FLETCHER** so that he can take up the appointment on October 1st, of director responsible to the board of the United Power Co., Ltd. for construction and supply. The United Power Company was formed recently to unite the nuclear engineering activities of Atomic Power Constructions, Ltd and the GEC and Simon-Carves Atomic Energy Group. Since April of this year Mr. Fletcher has been special adviser to the member for reactors.

DR. ARNO SIGVARD EKLUND of Sweden has accepted the post of director general of the International Atomic Energy Agency. The post was offered to Dr. Eklund by the board of governers of the IAEA and is subject to approval by the general conference. The present director general, Mr. Sterling Cole continues in office until the expiration of his term of office on November 30th, 1961. Born in 1911, Dr. Eklund is an eminent nuclear physicist. In 1958 he acted as secretary general to the second United Nations Geneva Conference on the Peaceful Uses of Atomic Energy. Dr. Eklund is chairman of the international board of management of the OEEC High Temperature Reactor Project DRAGON at Winfrith Heath.

D. H. HILL has been elected a member of the Société Royale Belge des Ingénieurs under the reciprocal agreement with the Institution of Nuclear Engineers. For some time Mr. Hill held the office of the nuclear energy attaché, United Kingdom Delegation to the European Community in Brussels.

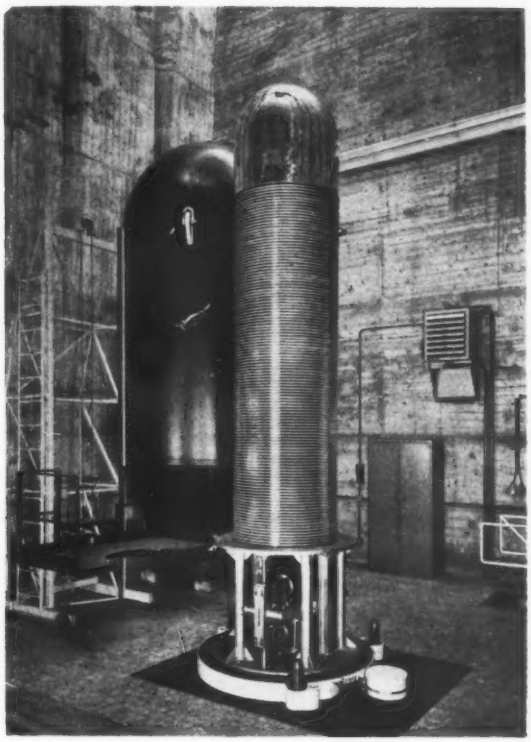
Westinghouse Electric Corporation have announced the appointment of **LLOYD B. KRAMER** as manager of nuclear reactor core development in their atomic power department at Pittsburgh.

DR. G. C. DALTON, one of Australia's leading atomic scientists, has died in Sydney recently at the age of 45, after a long illness. He was director of the research establishment of the Australian AEC at Lucas Heights. A New Zealander, he worked with the British AEA at Auckland University before going to Australia. (He was a Rhodes scholar in 1936). The Australian Minister for National Development, Senator Spooner, on Monday praised Dr. Dalton's work in helping to shape Australia's atomic energy research programme.

MR. H. A. C. McKAY, director of the CENTO Institute of Nuclear Science in Tehran has retired from that position after a full tour of duty. On his way back to the United Kingdom he made a final visit to the Central Treaty Organization headquarters in Ankara.△△△

New CISE Accelerator

3·5 MeV Van de Graaf inaugurated

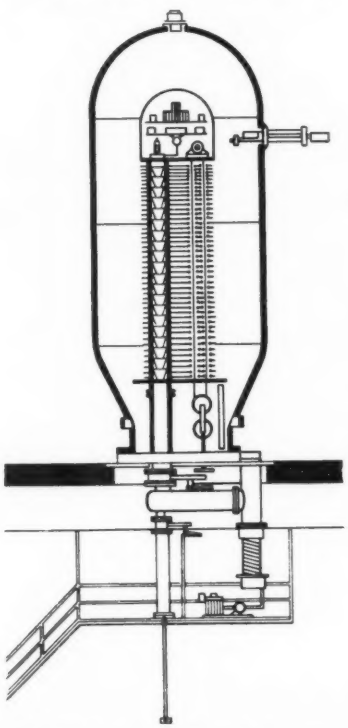


View of the 3.5 MeV Van de Graaf accelerator, now in operation at CISE, which was completely designed and built by scientists from the laboratories

THE inauguration was held recently at CISE laboratories in Segrate of a new apparatus for the study of the nuclear reactions mechanism and of the atomic nuclei structure.

The machine, a 3·5 MeV Van de Graaf electrostatic accelerator, was completely designed and built in Italy by a group of scientists and technicians from the CISE Nuclear Physics and Electronics Laboratories.

Test results have been quite satisfactory and the accelerator is now operating at 3·5 MeV. At present this machine is the most powerful accelerator in Italy for the acceleration of heavy particles (protons and alpha particles).



Simplified cross-section of the new 3.5 MeV Van de Graaf accelerator (1:100 scale)

The success achieved by CISE physicists crowns two years of intense work. During this time much skill and know-how has been acquired by the scientists concerned and this will now be put at the disposal of those industries and organizations interested in machines of this type.

The importance of this is realized when one remembers that all Van de Graaf accelerators, with their ever-widening field of application are supplied by a non-European country except in the rare case of accelerators built by large research centres for their own use.

At the moment the work schedule of CISE anticipates the development of nuclear physics researches in the field of medium energies, along the line of those which the Nuclear Physics Laboratory has been successfully following during the past years. Particular attention has been devoted to reactions (n,p) and (n,d) induced by 14 MeV neutrons produced, in their turn, by reaction $d+t=n+He$. This reaction is obtained by accelerating the deutrons with a 400 kV Cockroft & Walton accelerator which was also built by the staff of CISE some years ago. For the same purpose another 150 kV accelerator has been built recently.

As a result of the laboratory research programme a need was felt for an accelerator of higher energy and of greater versatility than those which had been utilized up to that time. This is why the Van de Graaf accelerator was built: with this accelerator it is possible to produce neutrons from 0 to 20 MeV or to utilize directly the protons and deutrons accelerated up to 3·5 MeV. Work in this field, besides being fundamental, will have an immediate practical use in the nuclear energy field since the results obtained will be required for the neutronic study of nuclear reactors.

Van de Graaf accelerators can be used of course for industrial applications (for instance, the gamma or neutron irradiation of different materials for testing purposes), for producing polymerization processes, for the sterilization of drugs, for industrial radiographies, in the field of activation analysis, etc. In medical science these machines provide useful sources of radiation in the radiotherapy field. △△△

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

New Irradiation Units

Two irradiation units for laboratory experiments with Co60 radiation have been developed by Atomic Energy of Canada, Ltd. They are the Gammacell 100 and 200, and are available in the U.K. through Watson & Sons (Electro-Medical), Ltd., Industrial Division.

The Gammacells 100 and 200 have a fixed ring of encapsulated Co60 rods into which the specimen is moved. The ring of Co60 rods is surrounded by a lead shield—no additional protection or special room is required.

The cell volume of the Gammacells 100 and 200 are $1\frac{1}{2}$ in. diameter $\times$ $4\frac{1}{2}$ in. high, and $3\frac{1}{2}$ in. diameter $\times$ $5\frac{1}{2}$ in. high respectively. Dose rates of up to 3×10^5 r/hr in the centre of the irradiation chamber are available.

Operation is by electric motor and timer. The specimen is placed in the sample chamber which is lowered into the ring of Co60 rods; at a preset time the sample is withdrawn. **(OCT 1)**

Personal Monitor

A self-contained radiation monitor, Scram I, based on a new Oak Ridge National Laboratory design, has been announced by Radiation Equipment & Accessories Corp. This 3·5 oz, pen-type dosimeter can be carried in the breast pocket and is designed to supplement and, in some cases, replace cart-mounted air monitors. The device produces an audible chirping sound through a miniature speaker.

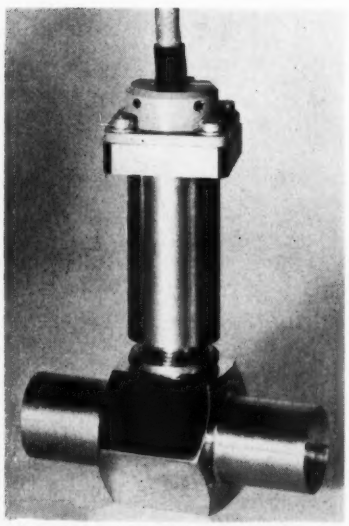
The detector is transistorized and has no switch and will operate continuously for about one year on a single mercury battery. At normal, safe background levels of radiation, Scram will chirp every two minutes. As radiation intensity increases, the chirps blend to produce a tone of rising frequency. At 1 r/hr, the sound frequency will be about 2,800 cycles/sec. The device is 6 in. long, $\frac{3}{4}$ in. diameter and costs $75. **(OCT 2)**

New Flowmeter

A new flowmeter primarily for use in the nuclear engineering field has been developed by Meterflow, Ltd.

The flowmeter has been designed for use on heat transfer systems employing either high temperature water or, alternatively, terophenyl. It has a maximum temperature rating of 400°C. and is suitable for welding into rigs. The bearings employed are manufactured from silver graphite and general construction is of stainless steel.

This meter can be used to measure either rate of flow or totalized flow to customers' requirements. Overall linearity of meter would be better than ± 1 per cent., repeatability better than $\frac{1}{4}$ per cent. **(OCT 3)**

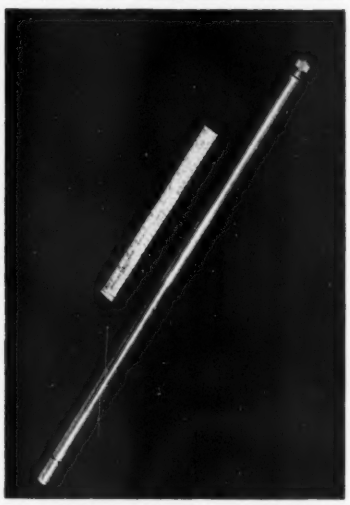


New flowmeter by Meterflow, Ltd., for use in the nuclear field

Proportional Counter

Plessey Nucleonics, Ltd., has introduced a series of proportional counters, PNI 1077, for use at low power levels in the installed neutron flux measuring channels of nuclear reactors. They are constructed of very high purity aluminium which, together with the use of an enriched boron lining and inert gas filling, permits immediate operation after long periods in high neutron fluxes. Ceramic-to-metal seals and ceramic insulators are employed to provide a robust counter suitable for plant use. The counter operates at relatively low voltages and a gas multiplication of 50 is obtained at about 750v. Higher gas multiplication may be used if required.

Irradiation of the counter in a high neutron flux activates the counter body. This produces a background count similar



Boron-lined proportional counter PNI 1077, by Plessey Nucleonics, Ltd.

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To: NUCLEAR ENERGY
147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT & MATERIALS *feature for October, 1961*

Item No's ....
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Enquirer's Name .....
Position .....
Firm .....
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to that obtained in high gamma fluxes, which may be rejected by operating the counter at an EHT value below that at which the pile up of residual activity and gamma pulses is sufficient to pass the discriminator threshold chosen. In practice after long irradiation in a thermal flux of 10^{10} n.v., this background can be rejected within ten minutes of the removal of the neutron flux. In most cases, therefore, where the counter is used for the low level neutron flux instrumentation of a reactor, no retraction mechanism is necessary to remove the counter once full power is reached.

The counter is also very resistant to long term radiation damage since, unlike BF_3, the counting gas is not affected by irradiation and the counting characteristics remain unchanged over a total dose of more than 10^{18} nvt. **(OCT 4)**

Radio-chromatogram Scanner

A two-dimensional radio-chromatogram scanner based on an original design by Professors E. B. Chain and M. Frank, has been developed by Gauging Systems, Ltd., Baldock, Herts., in conjunction with Beechams Research Laboratories, Ltd.

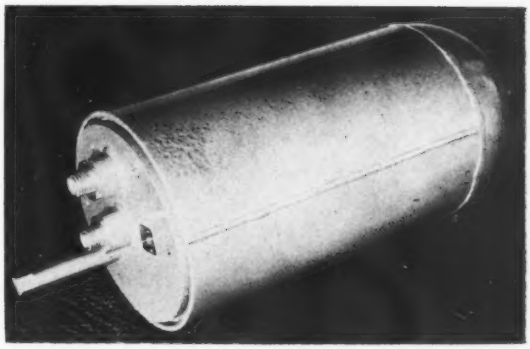
The radio-chromatogram is taped to the print out paper inserted into the electric print-out machine which carries out the scanning by moving the chromatogram between the end window GM tubes.

All counts are reduced to a four-figure print-out. The scanning period is variable at will up to 999 sec. **(OCT 5)**

Ionization Chamber

A new ionization chamber (PNI 1091) has been introduced by Plessey Nucleonics, Ltd. When used with a mixed argon-nitrogen filling, this chamber enables the response to gamma radiation to be made level down to about 100 keV. Below this figure it drops sharply.

The chamber can be made sensitive to thermal neutrons if required, and can be filled to provide approximate tissue equivalence to fast neutrons over a wide energy range.



Ionization chamber PNI 1091 by Plessey Nucleonics, Ltd.

The sensitive volume is 5 litres and various filling gases can be used at pressures up to 20 atm. A rigid electrode structure ensures low microphony and robustness is given by ceramic insulators and ceramic-to-metal seals.

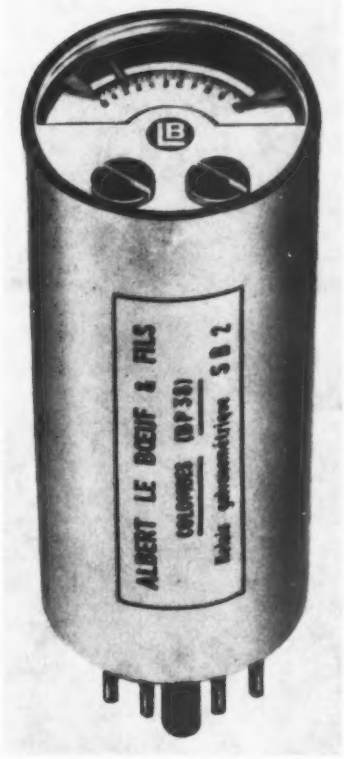
Sensitivity with 20 atm argon filling is $1{\cdot}3 \times 10^{-8}$ A/r/h; sensitivity with 20 atm mixed filling is $7{\cdot}7 \times 10^{-9}$ A/r/h. Maximum polarizing potential is 3 kV. **(OCT 6)**

New Relays

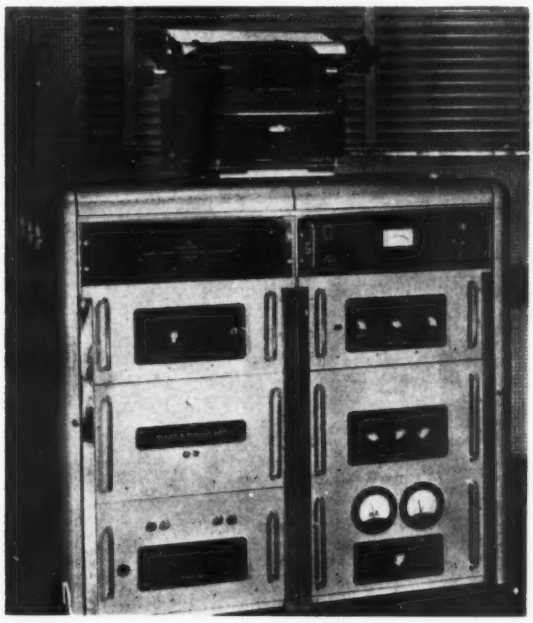
L. E. Simmonds, Ltd., of Harrow, Middlesex, have been appointed sole United Kingdom and Commonwealth concessionnaires for relays made by A. le Boeuf et Fils of Colombes, France. A new range of relays, hitherto unobtainable here, thus becomes available.

Typical of the new range is the moving coil relay Type SB 21. According to the type of coil-winding used, the operating current may be as low as 1μA with a 21KΩ coil or as high as 10mA with a 0·3 ohm coil. The relay may incorporate a rectifier or a thermocouple to enable it to be used on alternating currents of almost any frequency. The coil may be double-wound, providing differential deflection and this type may also have a logarithmic law so that the two currents are multiplied together (or divided one into the other).

The movement may be end or centre-stable. The contacts may be either 1 make plus 1 break or 2 make. The position of the moving contact and the variable fixed contacts are shown by pointers on a normal meter scale on the top of the relay, the fixed contacts being set by means of two adjusting screws adjacent to the scale. The insulation of the movement and the contacts from the frame is flashed-tested to 500v and the insulation resistance exceeds 10,000 megohms. The instrument is constructed in a substantial cylindrical metal case 3¼ in. long × 1½ in. diameter and is arranged to plug into a standard International Octal valve-holder. **(OCT 7)**



Moving coil relay type SB 21, marketed by L. E. Simmonds, Ltd.



Two-dimensional radio-chromatogram scanner developed by Gauging Systems, Ltd., in conjunction with Beechams Research Laboratories, Ltd.

NUCLEAR NOTES

Philippine power

RECENTLY issued by the IAEA is the report by the three-man commission which visited the Philippines in October, 1960. Nuclear power prospects in the Philippines during the next decade were investigated by the team and in the report it is suggested that a relatively large nuclear power station on the island of Luzon might be economically competitive with a similar conventional power plant towards the end of the 1960s. Detailed analysis is presented in the report of the probable comparative costs for conventional and nuclear power plant. In addition to this, advantages in using nuclear power are pointed out. These are (*a*) variety of fuel sources, (*b*) stability of price, and (*c*) the use of nuclear power plant could provide a useful check on rising oil prices.

IAEA Courses

FOUR courses have been organized by the IAEA on practical applications of nuclear energy. The first of these, " Use of radioisotope techniques in soil-plant aspects of agricultural and forestry research," is taking place at Wageningen from September 4th to October 27th, 1961. This will be followed by an " Advanced International Training Course on the Biological Effects of Radiation," starting on October 24th, 1961, and lasting four months at the Radioisotope Training Centre near Rehovot, Israel. The other two courses will be a four-week " International Training Course on Radiation Health and Safety " to be held in Chiba City, Japan, from October 24th to November 21st, 1961, and a " Regional Training Course in the Medical Applications of Radioisotopes " to be held from November 4th to December 28th, 1961, in Cairo. The courses to be held in Israel and the United Arab Republic will be financed from the funds provided under the United Nations Expanded Programme of Technical Assistance.

Accelerator conference

BROOKHAVEN National Laboratory acted as host for an International Conference on High Energy Accelerators held from September 6th-12th. Two hundred experts from all over the world attended the conference which was sponsored by the International Union for Pure and Applied Physics, the USAEC and Associated Universities, Inc.

Physics symposium

" HIGH Energy Nuclear Physics " is the title of a symposium to be organized by the Institute of Physics and The Physical Society in the Physics Department of Imperial College of Science and Technology on March 26th and 27th, 1962. Review lectures will be given on both theoretical and experimental topics in high-energy nuclear physics. Abstracts of work for inclusion in this symposium should be sent to Professor C. C. Butler, Physics Department, Imperial College, London, S.W.7, by January 1st, 1962.

Member No. 76

ON August 10th the Republic of Mali became the 76th member state of the IAEA. The application for membership by Mali was approved by the board of governors on September 30th, 1960.

GEC Nuclear plants

POWER generating companies can now buy a new series of nuclear plants from the U.S. General Electric Co. These plants have a nominal rating of 100, 200, 300, 400 and 500 MW and are offered at firm prices and with guaranteed net plant electrical output. With the exception of the 500 MW station, the new design of these plants eliminates the need for the traditional containment sphere or capsule. Design has been based on data obtained from Dresden nuclear power station.

Useful fission products

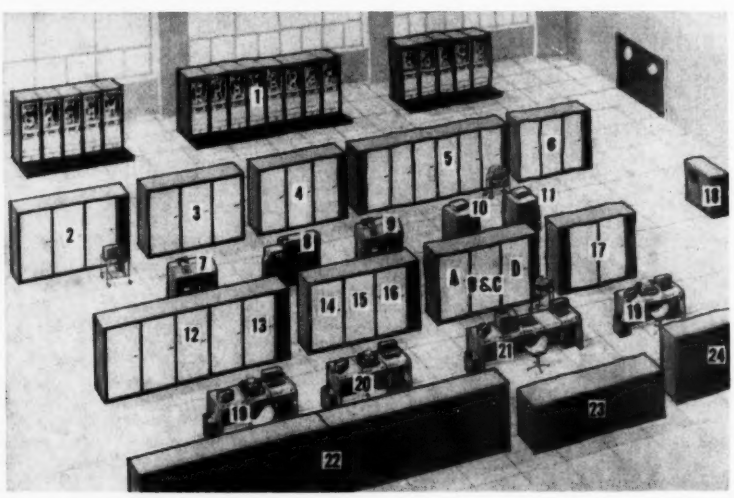
LARGE quantities of useful fission products are to be made available to industrial concerns in the U.S.A. for such purposes as fabrication into batteries. The Atomic Energy Commission has already undertaken a large radioisotope recovery programme at Hanford. The work is being done by the U.S. General Electric Co., and is at present mainly concerned with the recovery and processing of strontium-90 and caesium-137. Final processing of both these isotopes is carried out at Oak Ridge but ion-exchange equipment designed for the experimental purification of promethium at Hanford has been modified and is now in use for the initial purification of strontium.

IAEA publications

EIGHT new publications issued recently by the IAEA are listed below: " Selected topics in radiation dosimetry," proceedings of a symposium held in Vienna, June, 1960; " Fuel element fabrication with special emphasis on cladding materials," Vol. 1, proceedings of a symposium held in Vienna, May, 1960; " Small and medium power reactors," Vol. 1, proceedings of a conference held in Vienna, September, 1960; " Powder metallurgy in nuclear reactor construction," by H. H. Hausner, Polytechnic Institute of Brooklyn, New York, Review Series No. 11; " The packaging,

UKAEA Atlas Installation

Proposed layout for the Atlas Computer installation at the National Institute for Nuclear Research. Key:—1 Tape units; 2 Tape co-ordinator; 3 Drum unit; 4 Core store; 5 Core store co-ordinator; 6 Core store; 7 Card reader; 8 Card punch; 9 Card reader; 10 Hammer printer; 11 Hammer printer; 12 Tape telephone exchange; 13 Tape control; 14 Peripheral co-ordinator; 15 Drum co-ordinator; 16 Work store; 17 Fixed store; 18 Power supplies; 19 Unit furniture; 20 Slave control; 21 Main control; 22 Power supplies; 23 Battery box; 24 Distribution panel



NUCLEAR NOTES

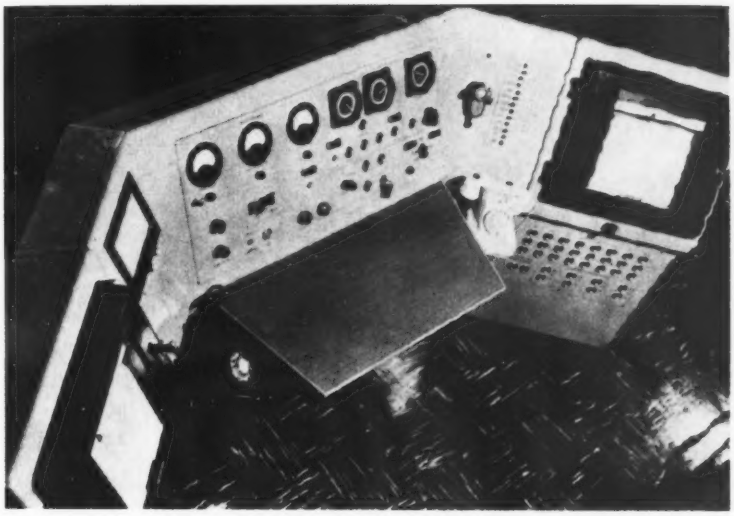
transport and related handling of radioactive materials," by F. R. Farmer, UKAEA, Review Series No. 12; "Radiation-initiated polymerization and graft polymerization," by R. Roberts, UKAEA, Review Series No. 13; "Radioactive isotopes and their production under neutron irradiation," by N. E. Brezhneva and S. N. Oziraner, Academy of Sciences, Moscow, U.S.S.R., Review Series No. 15; "Safe operation of critical assemblies and research reactors," a manual prepared by the Agency's reactor experts.

AGR tests

TESTING was successfully carried out recently of the 135 ft diameter containment building for the AGR at Windscale. Results for sub-atmospheric, strength and leak tests were quite satisfactory.

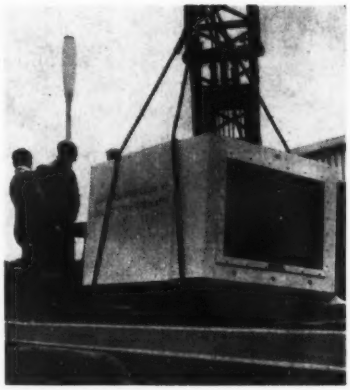
Atlas computer

NIMROD's injector was recently successfully operated for the first time. Commissioning of the injector began on July 1st and the linear accelerator has now accelerated a proton beam to the design energy of 15 MeV. Work began on the 7,000 MeV proton synchrotron in August, 1957, and is expected to be completed during 1962. It has also been announced recently that an Atlas electronic digital computer has been ordered for the National Institute for Research in Nuclear Science. The cost of this machine will be somewhere in the region of £1½m. This computer has only recently been developed by Ferranti, Ltd., in conjunction with scientists at Manchester University and the prototype is at present in the process of assembly. Although the machine will be built at the Institute, its capacity is so large that it will be able to deal with the needs of many other research organizations. Much of the computation required at the Institute in connection with work carried out on the proton synchrotron, will be done on an Orion computer which is to be installed soon. Work beyond the capacity of the Orion will be carried out on the Atlas computer. Another major user of the Atlas is expected to be the Culham Laboratory team at Harwell. This team is at present studying the behaviour of a mass of plasma when acted upon by electric and magnetic fields including the magnetic field produced by its own movements. The complexity and importance of this work are such that computations of great intricacy and size are required. Facilities will also be provided on Atlas for work by the universities and other government departments.



Control console recently installed in the Materials Testing Reactor at Dounreay. It has been designed to carry all controls required for starting up and shutting down the reactor as well as the most important parameter instruments. Reactor start-up, signalling, shutdown, scram-signalling and alarm push-buttons are housed in the centre panel together with reactor control arm position indicators and controls. The left-hand pedestal contains a large recorder for indicating heavy water differential temperature, and a 24-way annunciator panel. The Ion Chamber Recorder for indicating reactor power and the controls for a public address system are contained in the pedestal on the right

Unloading one of four radiation shielding windows ordered by the UKAEA for a series of cave facilities at Windscale. These windows, made at the Chance-Pilkington Optical Works are equivalent in protective properties to nearly six feet of concrete. Each window contains six blocks of glass, five of which are 10¼ in. thick and the other 9¼ in. thick. Reflection at each glass surface has been reduced by the introduction of oil into each complete unit between the blocks. The windows each weigh 7 tons



Radiation course

THE fifth advanced course in "The Principles of Radiation Protection" will be held in the Harwell Reactor School from October 25th, 1961, to January 30th, 1962. The course, which comprises lectures, practical work, demonstration and visits, is intended for graduates or persons of graduate standard either entering or already working in the field of radiological health and safety. The course will cover a wide field of fundamental background knowledge and will deal with principles rather than with particular techniques. A high academic standard is set, but since few academic courses cover all the necessary subjects, the course of lectures will begin with first principles, and will not require previous specialized knowledge. Some of the lectures will be given by the staff of the school, but the majority will be delivered by experts from Harwell and other UKAEA establishments. It is also hoped, as on previous courses, to have lectures from experts from the Medical Research Council, the Agricultural Research Council, the Central Electricity Generating Board, the Institute of Cancer Research, the Radiological Protection Service and Ministry of Housing and Local Government. The four courses held so far have proved to be very popular. The majority of students attending these courses have come from the UKAEA, with a small number from other organizations in the United Kingdom and from countries in Europe and Asia. The theoretical part of the course consists of about 110 lectures under three main headings: Basic scientific principles (about 50 lectures); Principles of Radiation Protection (about 50 lectures); General topics (about 10 lectures). Practical work will cover between 15 and 20 experiments, including some designed to illustrate basic principles and others intended to illustrate the principles of protection. The programme of visits will include installations at Harwell and at some of the other establishments of the Research Group, and there will also be a tour of some of the UKAEA factories to acquaint students with the problems in health physics and safety in the main types of plants and installations of the atomic energy industry. It is also hoped, as on previous courses, to visit units of the

NUCLEAR NOTES

Institute of Cancer Research and the Radiological Protection Service. The fee for the course is £250, exclusive of accommodation, and application forms and further details can be obtained from The Manager, The Reactor School, Atomic Energy Research Establishment, Harwell, Berkshire.

AtomFair-61

SPECIAL passes for business, scientific, industrial and government personnel to AtomFair-61 are now available on request from the Atomic Industrial Forum, 850, Third Avenue, New York, 22. AtomFair-61 will be held on November 6th-9th at the Conrad Hilton Hotel, Chicago, Illinois, in conjunction with annual meetings of the American Nuclear Society and the Forum. More than 100 industrial firms are expected to participate in the Fair which is an annual display of the products, equipment and services related to commercial applications of nuclear energy.

Weather station

THE world's first isotope-powered automatic weather station is now sending in reports every three hours from Sherwood Head on Axel Heiberg Island. The station was designed and built for the USAEC by the Martin Company. Power is derived from about 1 lb of strontium-90 held inside an insoluble compound and sealed in a corrosion-resistant metal capsule. The whole is housed in a cylindrical insulated container about 8 ft long, the bottom 5 ft of which are buried in permanently frozen ground. Besides the usual meteorological instruments the station contains a Sr90 heat generator and thermocouples, batteries and a converter. Three-quarters of a ton of lead are used to shield the station. Excess heat from the strontium is used to maintain an interior working temperature of 70 F. Usable power will be produced for 10 years and the station can be left unattended for a period of two years.

Oldbury station

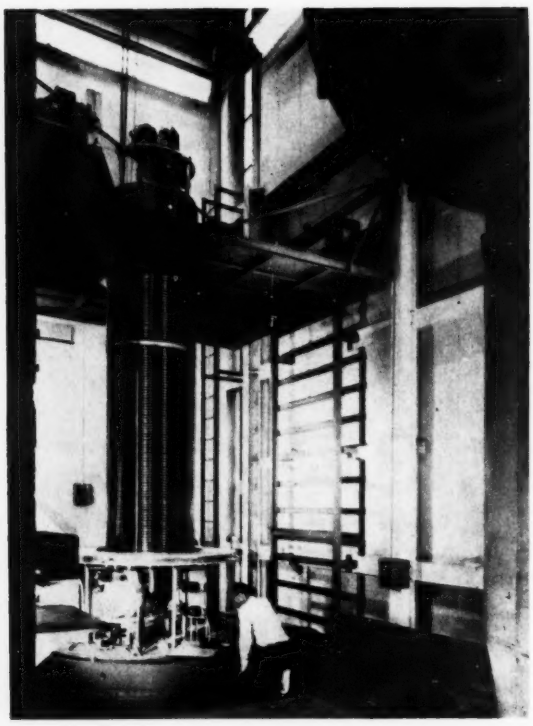
TENDERS have now been received by the CEGB for the 550 MW nuclear power station to be built at Oldbury-on-Severn, Gloucestershire. That submitted by The Nuclear Power Group has two reactors each enclosed in a prestressed concrete pressure vessel.

Springfield laboratories

SITE works and the erection of buildings for the fuel element development laboratories are in progress at Springfield Works, Salwick, near Preston. The contract, awarded by the UKAEA to J. Gerrard & Sons, Ltd., civil engineering contractors, is scheduled for completion in April, 1962.

Full-power loading

EXPERIMENTS have been carried out in the Calder Hall reactors to find out what happens when fuel elements are loaded into a reactor on full power. The CEGB civil power stations have been designed to allow fuel replacement while the reactors are running continuously and the Calder experiments were to check that the fuel elements would withstand the temperature changes involved. The Calder reactors were designed for complete fuel changing with the reactors shut down and depressurized. For these tests, therefore, it was necessary to adapt existing charge and discharge equipment to provide on-power fuelling conditions. The element to be tested was suspended from a spare control rod mechanism modified to give the required speed of insertion and to hold the element in the required position in the reactor. The gas flow through the channel was adjusted so that the test element, by virtue of its own heat production and that of the other elements already in the channel, would experience the required temperature changes. This simulated the actual civil station loading conditions where it is expected that the elements (perhaps after some preheating in the charge machine), will be subjected to a further rapid increase in temperature when inserted into the core. On completion of the experiments, the irradiated elements were sent to the laboratories for metallurgical and radiographic examination by remote handling. These tests revealed no significant effects on the elements as a result of on-load charging. A second experiment was carried out to see what effects frequent variations in temperature—thermal cycling—had on fuel elements. The elements already in a civil reactor would be subject to these changes every time an adjacent channel was charged or discharged. To simulate these changes, two control rods were oscillated up and down in the reactor core to produce temperature variations in the neighbouring channels. The oscillations were continued for approximately 13,000 cycles and the nearby fuel elements then discharged and examined. Here also no measurable ill-effects were found.



This 5.5 MeV research accelerator has been purchased recently from High Voltage Engineering Corporation by the Southern Universities Nuclear Institute of South Africa. The accelerator, shown here under construction in the U.S.A. will be used for nuclear structure investigations and will be equipped with a precise beam-bending and analysing magnet which will direct stabilized protons into nuclear targets. A switching magnet will make it possible to conduct several experiments concurrently

Burn-out elements

HOLLAND's National Council for Industrial Research T.N.O. has been commissioned by Euratom to investigate the burn-out of fissile material elements. In some types of reactors heat-insulating vapour bubbles may be formed on the elements. As a result, the temperature of such an element rises rapidly and holes may occur in the wall, so that the highly radioactive fission products may come out. The Röntgentechnische Dienst N.V., Rotterdam, has received an order from Euratom for investigating the possibilities and restrictions of the methods at present available for testing welds in very thick parent metal by means of ultrasonic waves, etc. The Röntgentechnische Dienst (Röntgen Technical Service) will also use apparatus available abroad and design special equipment for the ultrasonic tests.

Canada-India station

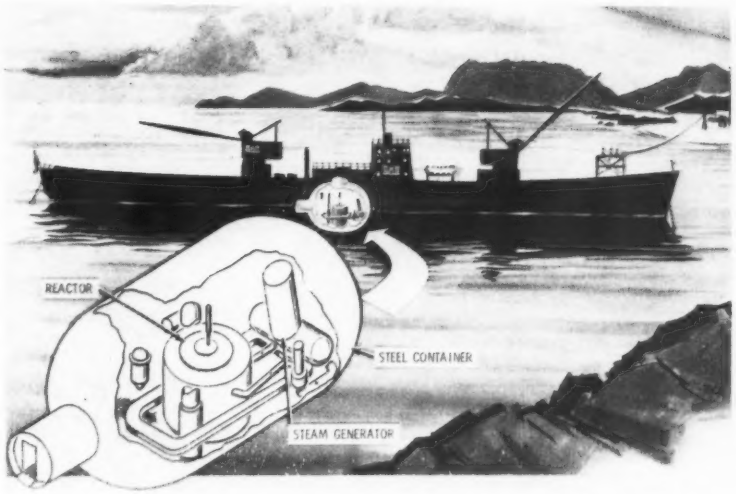
CANADA and India will undertake a joint study of the cost of building in India a nuclear power station of Canadian design. Following a request from the Government of India for such a study, the federal government has authorized Atomic Energy of Canada, Ltd., to carry out the study

NUCLEAR NOTES

with the Indian Atomic Energy Commission. The plant would be similar to the Douglas Point nuclear power station now under construction at a site mid-way between Kincardine and Port Elgin, Ontario, on the eastern shore of Lake Huron. The Douglas Point plant, which is to have an electrical output of 200,000 kW when it goes into operation in 1965, will use natural uranium for fuel and heavy water for moderator. The Indian station would be as nearly identical as possible to the Douglas Point station, but some minor modifications would probably be required owing to different climatic and geographical conditions. The Planning Commission of India has authorized the Indian Department of Atomic Energy to select a suitable site for the power station in the general area of East Punjab-Delhi-Rajasthan-West U.P. The study will determine the overall cost of building the Canadian type power station in India together with details of the cost of parts which could be supplied by India and the cost of remaining components that would have to be imported. The joint study will take about six months to complete and Canadian engineers are now in India for initial discussions. The decision on whether or not the plant will be built will be taken by the Government of India when costs have been determined. This project is a continuation of the close co-operation in the nuclear energy field which has existed between India and Canada for several years. The two countries built the Canada-India reactor at Trombay, India, and put it into service in 1960. This reactor is similar to the NRX research and engineering test reactor at the Chalk River establishment of Atomic Energy of Canada.

Uranium combine

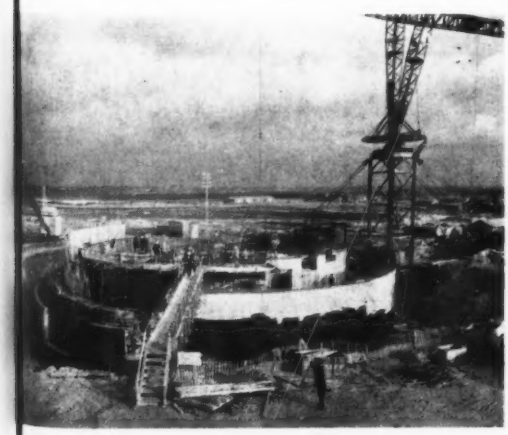
IT has been announced in Darwin that two uranium mining companies have combined to form a new firm to open up mineral deposits, preferably in the Northern Territory. The new organization will explore prospects of opening up other mines before current uranium contracts with Britain expire. The two uranium companies, United Uranium and South Alligator Uranium, have combined to form a new company called Group Ventures, with head offices in Melbourne. The new company wishes to continue its operations in the Northern Territory, but will investigate potential mineral deposits in other parts of Australia as well.



Artist's impression of a floating nuclear power plant ordered recently by the United States Army Corps of Engineers from the Martin Company. The 10,000 kW plant is to be installed in the hull of a reconditioned and modified surplus Liberty ship. Final cost is expected to be in the region of $16,998,127. Under war conditions floating power plants are often required, but they present considerable supply problems. Using nuclear plant eliminates these. The nuclear fuel core will be less than four feet in diameter and little more than three feet high. It has been proposed that fuel should consist of uranium dioxide pellets encased in stainless steel rods of 2 in. diameter. Lead and liquid shielding weighing up to several hundred tons will be used around the core and collision-proof barriers will be used

Research proposals

THE U.S.-Euratom joint Research and Development Board have announced that a total of 56 proposals for research and development work amounting to approximately $13·2m. has been authorized within the Community and the United States since the initiation of the programme on December 23rd, 1958. A majority of these proposals are now under contract: a few programmes have been completed and the others will start in the near future. Twenty-eight Community and 11 United States organizations are represented in the work authorized, much of which involves close collaboration between Community and U.S. industrial groups. U.S. contractors are financed by the USAEC and Community contractors by Euratom.



Dry 'DRAGON'

The presence of ground water at Winfrith has been one of the greatest problems to be overcome during the construction of the DRAGON reactor and its ancillary buildings. To counter this a liquid asphaltic composition has been used above and below ground level on all buildings at the research station to provide a permanent waterproof and vapour-proof barrier. Our photograph shows the reactor building during construction. The asphaltic composition is being applied to the external concrete walls 25 ft. below ground level

Annual Dinner

Tickets for the Annual Dinner of the Institution of Nuclear Engineers are now available from the Secretary. Applications must be accompanied by remittance (15s. each, wines extra)

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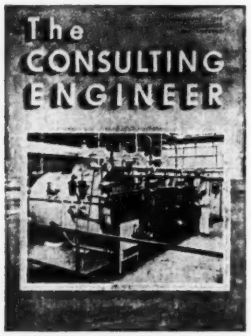
Correction

THE caption to the photograph in the bottom left-hand corner of page 340 of our August issue incorrectly refers to Dr. Ing. Prof. Alessandra Banfi, president CIREN. This should read Prof. Dario Schena Sterza, Director General, Founder, and Manager of CIREN. △△△



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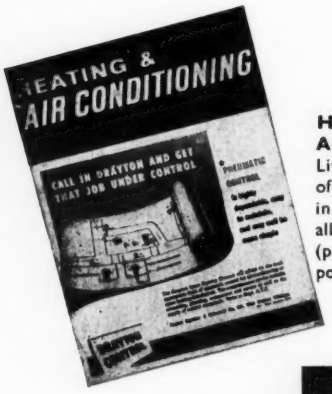

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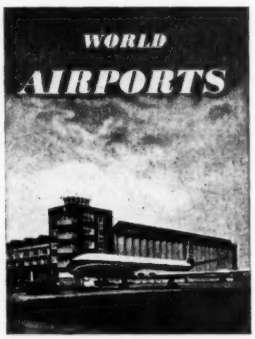

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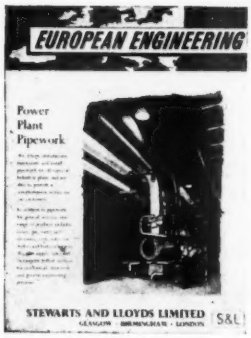

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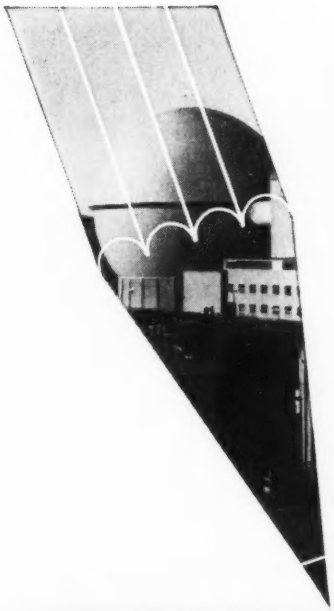
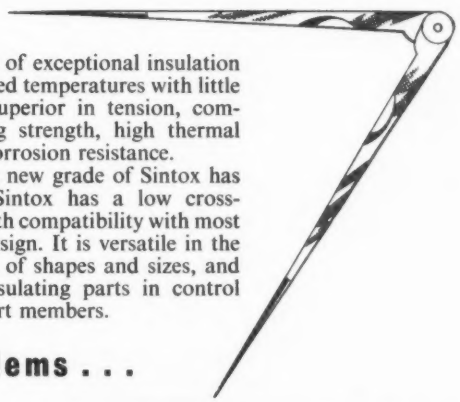


material answer



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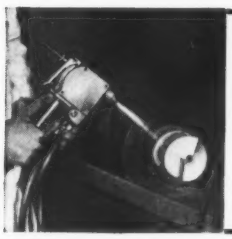

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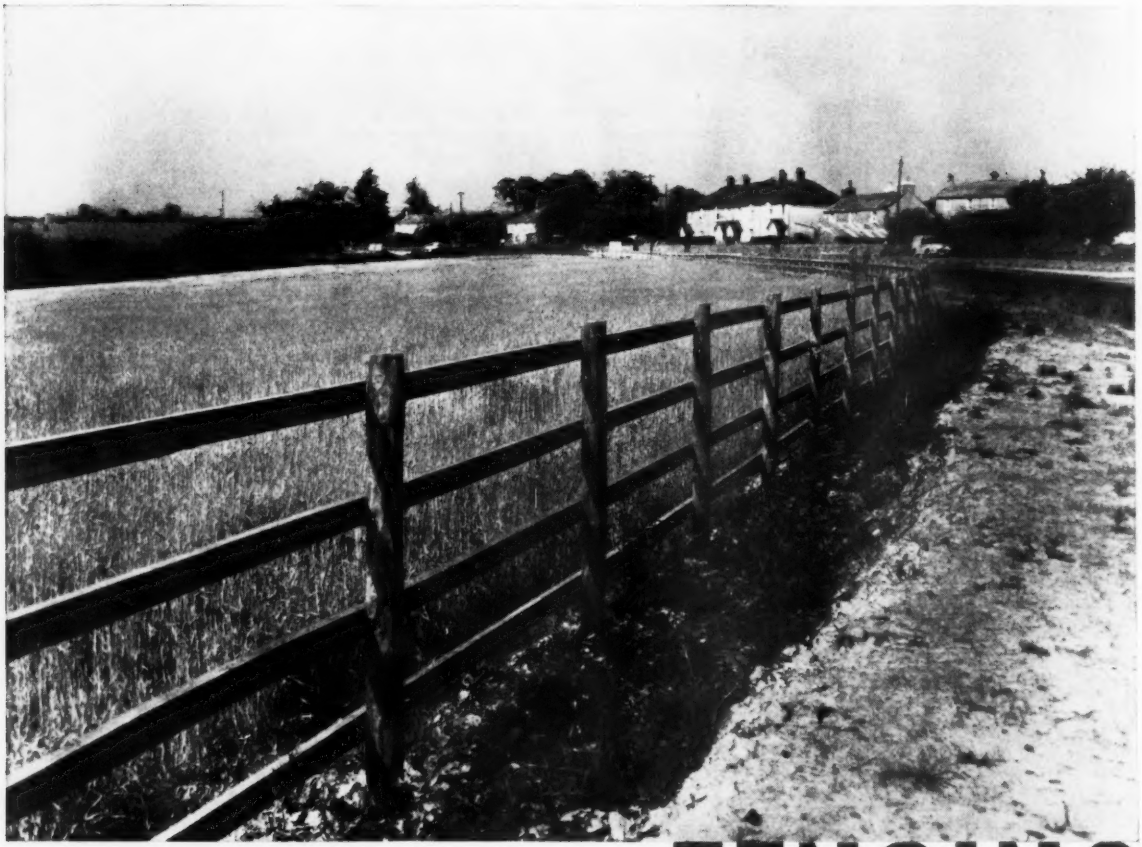

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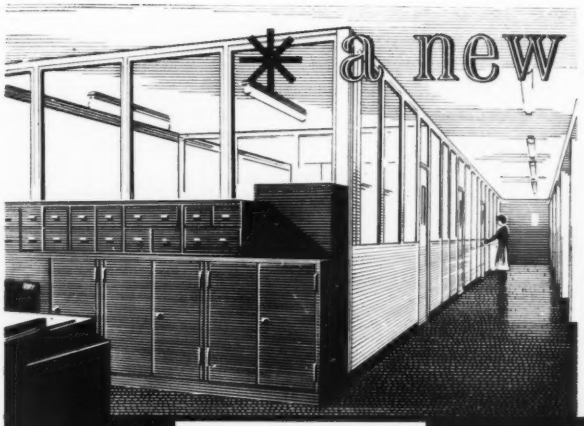

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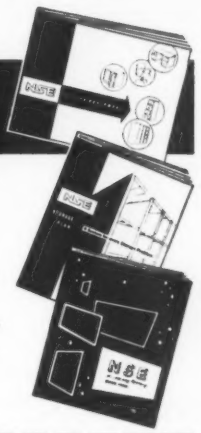

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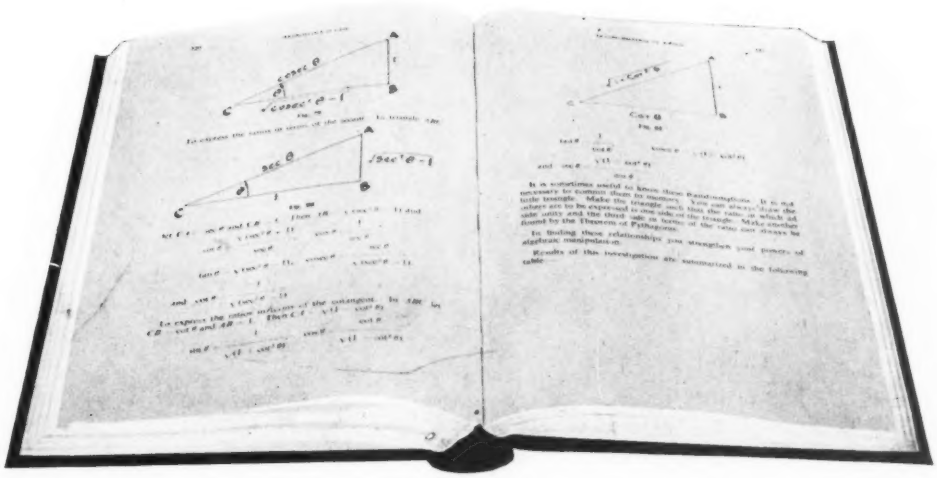

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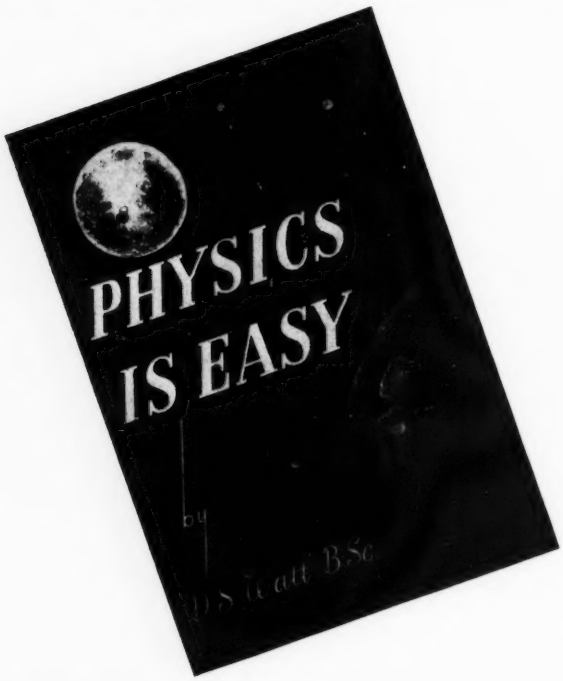

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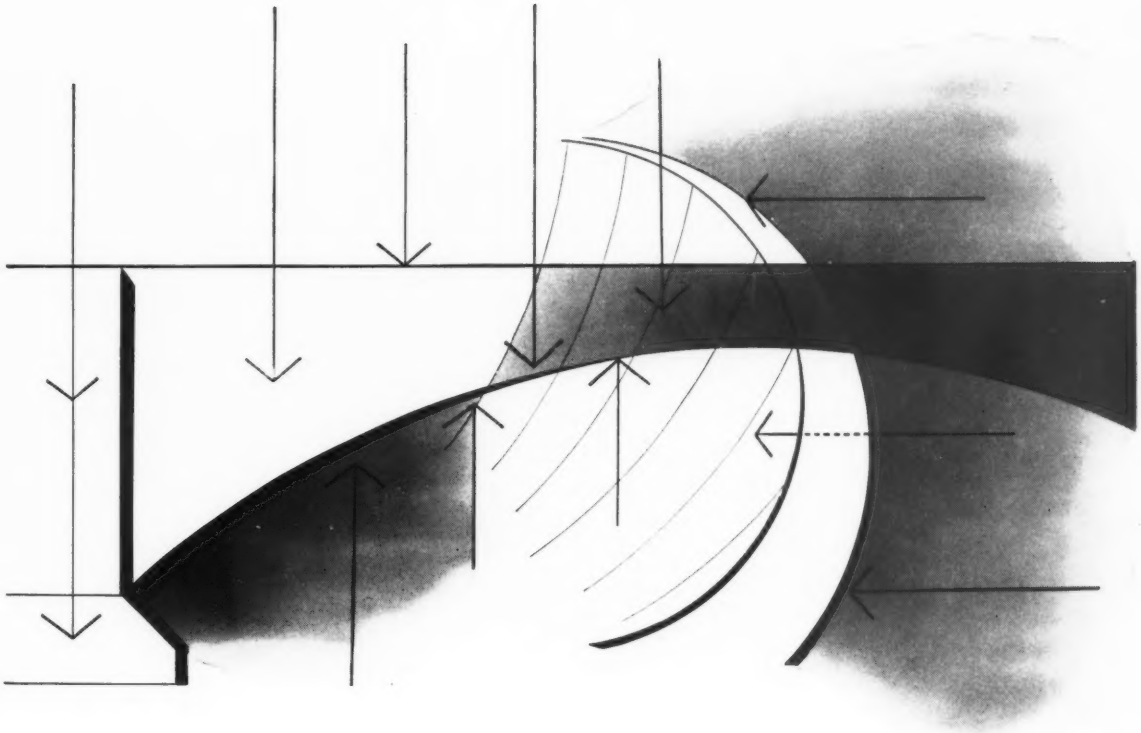

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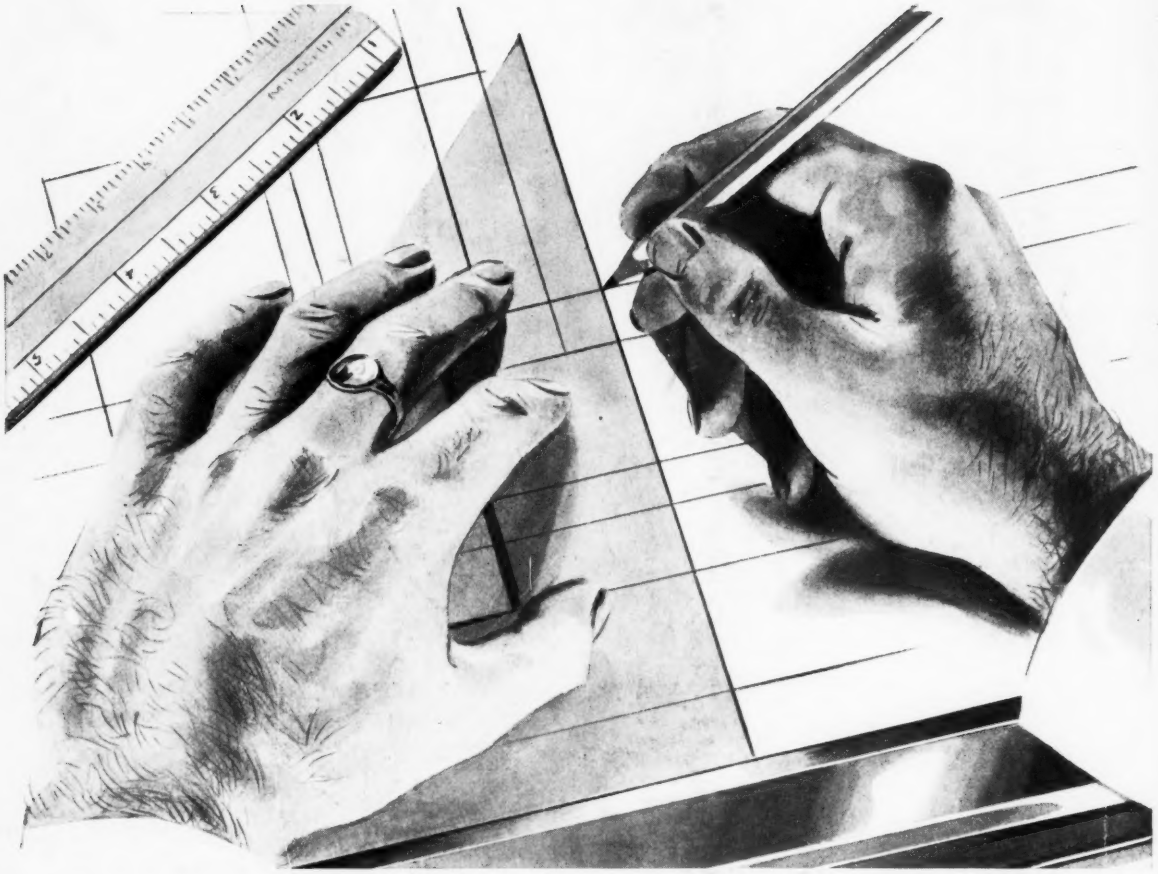

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